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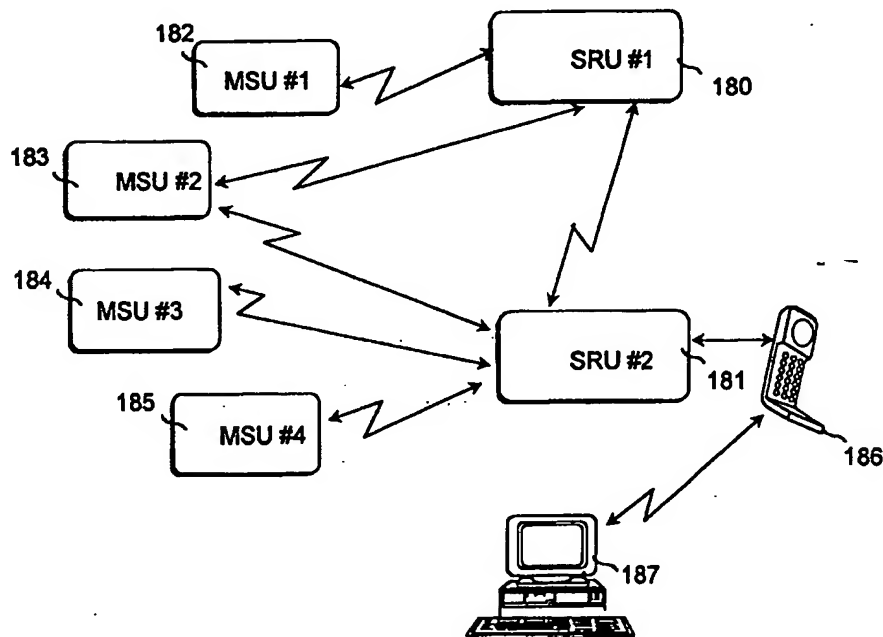
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(54) Title: MONITORING METHOD AND APPARATUS

(57) Abstract

A combined portable monitoring, tracking and searching system, comprising one or more monitored and/or searched units (MSU) and one or more monitoring and searching units (SRU), wherein the MSU comprises processing means, memory means, display and/or audio means, a transmitting/receiving antenna, a spread spectrum receiver to receive modulated spread spectrum data and to convert it to baseband data, a spread spectrum transmitter, a data spreader, a synthesizer or frequency generator, and a correlator to correlate spread spectrum data received by said spread spectrum receiver with a known Pseudo Noise (PN) sequence; and, the SRU comprises processing

means, memory means display and/or audio means, a transmitting/receiving omnidirectional antenna, a transmitting/receiving directional antenna, a spread spectrum receiver to receive modulated spread spectrum data and to convert it to baseband data, a spread spectrum transmitter, a data spreader, a synthesizer unit or frequency generator, a correlator to correlate spread spectrum data received by said spread spectrum receiver with a known PN sequence, and delay measurement means, to measure the time elapsed from the beginning of a first transmitted sequence to the beginning of one or more of the sequences received from a MSU in response to said first transmitted sequence.



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-1-

MONITORING METHOD AND APPARATUS

Field of the Invention

The present invention relates to the monitoring, tracking and searching of moving and stationary persons, animals and objects. More specifically, the invention relates to a system that combines monitoring, two-way messaging and searching capabilities, in a local area, of a person or group of persons, animals, objects and places.

BACKGROUND OF THE INVENTION

The necessity of monitoring persons, animals or objects and find their actual location when required has led to the development of many location systems, some of which are commercially available. Conventional location systems, enable to calculate the location of a person or object, using different methods. The main methods are:

Global Positioning System (GPS) based systems: These systems are based on the use of a GPS receiver that receives signals from at least three GPS satellites and calculates its absolute position. The calculated coordinates are then transmitted by any wireless communication means to a center or person who wants to know the location of the person with the GPS receiver. Normally, it is necessary to put those calculated coordinates on a map, in order to allow the searching of this person. The communication means used for data transmission of the calculated GPS coordinates are

-2-

usually mobile radio, satellite and cellular telephone networks. Although the GPS system may be used worldwide, a given commercial system is normally limited by the coverage of the specific communication network used to transmit the GPS coordinates, and its message transfer capacity. Beside the standard GPS system used worldwide, there are several other Low Earth Orbit (LEO) satellites systems used for communication and location.

Multi-lateration systems: These systems use land-based fixed base stations to locate a moving object or person. This location is calculated by the network control center based on the Difference in Time of Arrival (DTOA) between different base stations, of a known signal transmitted by the moving object or person. The located unit transmits its identification/location signal after it was paged from a center, or when triggered by an event in the located unit or at preprogrammed intervals. This location system is limited to well defined areas covered by the ground base stations and due to its system architecture it has a limited capability to perform continuous monitoring of a specific unit. Also with this system it is necessary to put the calculated coordinates on a map (normally a computerized map), in order to allow the searching of the located unit.

Cellular telephone systems: These systems use the infrastructure of the cellular telephone systems to locate a telephone unit. The unit is roughly located by knowing the cell in which it is located or more accurately

-3-

using geometrical methods and by measuring the Time of Arrival (TOA) at different base stations.

Direction finding svstems: These systems use ground base stations with directional finding capabilities to calculate the location of a unit transmitting a known signal. The location is basically calculated by intersecting the direction lines found by each of the base stations. Some systems replace the ground base stations with mobile stations equipped with expensive phase array antennas (normally used for stolen vehicle recovery).

Loran-C systems: This is a pulsed radio navigation aid, which gives position in the horizontal plane. These systems operate in the 90 to 110 kHz frequency band and consist of transmitting stations arranged in groups forming chains. At least three transmitting stations make up a chain. Chain coverage is determined by each stations transmitted power, the distance between master and secondary stations, and the geometric arrangement between stations within the chain. Loran-C systems are used for navigational purposes and other tracking and location applications. Some systems combine GPS and Loran-C positioning systems to improve accuracy and availability.

All the systems described above use a radio communication infrastructure that enables them to locate the unit and/or to transmit the location data to a

-4-

system center. Due to the complexity of those systems, their limited communication traffic capacity, cost and the regulation approvals required, they cannot be operated and used by single persons for their personal use. Persons who want to make use of any of those systems need to pay service fees to a company that operates the system and are limited to such specific applications, for which the use of the system is applicable and cost effective. Moreover, in many cases, the required communication infrastructure, which is cumbersome and expensive, is only found in well defined areas where the system coverage is justified by economical factors.

Beside those systems, normally used for relatively wide area location, there are other systems that use simple communication methods and in some cases ranging methods to monitor a person or group of persons. Those systems allow the user to maintain some type of contact (using wireless communication) with a person or group of persons. Some systems, normally used for monitoring offenders under house arrest, are characterized by giving an alarm when a monitored person is at a distance from a base station greater than a predetermined threshold distance. The base station is connected to a telephone line and alerts the police or the security personnel that the threshold distance has been exceeded. Such systems are inherently limited for alert purposes only and do not have the capability to search or locate the monitored person even after the threshold distance has been exceeded. Moreover, they do not give the monitored person any indication about his distance from the base station (if the alarm has not been

-5-

activated), or give any indication if the person is closer than a predefined distance, to a specific site. Examples of such systems are found in U.S. Patent Nos. 5,448,221, 5,255,306 and 4,980,671.

U.S. Patent No. 5,448,221 describes a monitoring system for persons under house arrest, which only provides an out-of-range warning alarm to both the monitored person and to a base station connected to a telephone line.

U.S. Patent No. 5,255,306, describes a similar system to monitor parolees, including a low power tag worn by the parole which transmits an ID signal to a field monitoring device, that reports to a host computer via a cellular telephone network. Also U.S. Patent No. 4,980,671 describes a system including a small transmitter secured to the body of the confinee, a remote station located within the confinement area and a central station.

Some other systems, used for elderly and disabled people assistance, use very simple communication methods to transmit a panic signal and request assistance. Those systems lack of any ranging and searching capabilities unless they use one of the location systems mentioned above. Other system are designed to monitor personnel moving within a defined closed area, such as a prison or a power plant, and comprise means for broadcasting a distress signal if the person wearing the device is in danger. One such system is described in U.S. Patent No. 5,218,344 which describes a method and system for monitoring personnel in an institution such as a correctional

-6-

facility, hospital, school or military installation, and includes a computer connected with one or more stationary transceivers in a defined area of the facility, and a portable transceiver unit worn by each individual who is to be monitored.

From the above description of all the systems and technologies, it can be clearly seen that there is no system that, on one hand, combines simple to use monitoring, tracking and searching capabilities, and on the other hand, is simple, may be operated anywhere, without the use of any fixed infrastructure and without the intervention of any service provider. In view of the above, it is an object of the invention to provide a monitoring, tracking and searching system that overcomes the deficiencies of conventional location or monitoring systems.

It is an object of the invention to provide a system which is simple to use, inexpensive, may be operated anywhere, without the use of any fixed infrastructure and without the intervention of any service provider and which obviates the aforementioned and other disadvantages of prior art systems.

It is another object of the invention to provide a system and apparatus which can be used both to alert one or more persons that another person is found at a distance greater or shorter than a desired predetermined

-7-

distance, on the one hand, and which can be used to locate such a person, on the other.

It is still another object of the invention to provide a system and apparatus which is not limited to a predetermined setup, but which can be employed to host a plurality of guest personal devices.

Other objects and advantages of the invention will become apparent as the description proceeds.

SUMMARY OF THE INVENTION

Thus the invention provides a monitoring, tracking and searching system, that may be used for monitoring moving or stationary persons, animals or objects and searching them, up to a maximum distance derived from the system capabilities and the environment, and without using any additional communication infrastructure.

The system consist of two or more portable units that maintain between them two-way wireless communication. Each unit may monitor, track and search one or many other units, while each unit may be monitored and searched by one or many units.

Units with monitoring, tracking and searching functions, include spread spectrum ranging and direction finding capabilities while other units

-8-

monitored and searched by the first ones include a spread spectrum transceiver. The units with monitoring, tracking and searching capabilities may also be monitored, tracked and searched by other unit or units.

All the system preferably operate in the ISM band, which is used in the US and worldwide for unlicensed spread spectrum communication. Both monitoring and monitored units are portable and in some cases integrated or connected to other communication or electronic devices. In addition both type of units include two-way messaging capabilities that enable them to transmit and receive messages from other units.

The system units make use of several technologies in order to achieve improved performance in noisy or problematic communication environments. The units communicate each to other using spread spectrum techniques. They use direct sequence coding to take advantage of the processing gain and ranging capabilities inherent in this coding technique. In addition they use frequency hopping in order to improve the performance in multipath conditions, strong fading conditions, to overcome nulls and narrow band interference sources that may be present in the working band. In some cases the units may use diversity antennae to improve even more the receiving conditions in cases of fading or nulls. Using those techniques, the directional antenna and an adaptive communication algorithm, the units of this system can achieve a superior performance than those of the prior art.

-9-

The monitoring unit measures the distance to one or more monitored units using spread spectrum ranging methods. The measured distance may be also transmitted to the monitored unit. Both unit may display the measured distance and/or use it to perform preprogrammed functions (i.e. activation of alarms or external signals, transmission of messages between the units, etc.). Distance measurement is performed periodically or when requested by the user or by a monitored unit, or as a result of an external signal.

The monitoring unit may at any time track, search and locate the monitored unit using the directional antenna and the distance measurement capability. In addition, monitored units may use the measured distance transmitted to them to search the monitoring unit. This capability is also enhanced by an audiovisual mechanism that allows the user of the monitored unit, to easily know if he is approaching the monitoring unit or moving away from it. Monitoring units may also have this feature to facilitate and speed-up the searching process.

Monitoring units may rely information to other monitoring units and in that way enhance the distance and effectiveness of the monitoring, tracking and searching process. The monitored and/or searching units can be incorporated in other existing devices, such as cellular phones, beepers, car alarms, or any other suitable device.

Brief Description of the Drawings

In the drawings:

Fig. 1 schematically shows a monitored/searched unit (MSU), according to one preferred embodiment of the invention;

Fig. 2 schematically shows a monitoring and searching unit (SRU) according to one preferred embodiment of the invention;

Fig. 3 schematically shows a monitoring and searching unit (SRU) with directional antenna array, according to a preferred embodiment of the invention;

Fig. 4 schematically shows a monitoring and searching unit (SRU) with smart card reader, according to another preferred embodiment of the invention;

Fig. 5, schematically shows a monitoring, tracking and searching unit (SRU) with PCMCIA interface, according to another preferred embodiment of the invention;

Fig. 6A and 6B illustrate the correlator units of the MSU and SRU, according to a preferred embodiment of the invention;

Fig. 7 illustrates an MSU or SRU according to another preferred embodiment of the invention;

Fig. 8 illustrates an MSU according to another preferred embodiment of the invention;

-11-

Fig. 9 illustrates an SRU according to a preferred embodiment of the invention;

Fig. 10 schematically shows a number of antenna direction indicators according to a preferred embodiment of the invention;

Fig. 11 shows transmit/receive timing;

Fig. 12 shows frequency hopping messaging, according to another preferred embodiment of the invention;

Fig. 13 illustrates a network operation according to another preferred embodiment of the invention;

Fig. 14 is a flowchart illustrating an acquisition process according to another preferred embodiment of the invention; and

Fig. 15 is a flowchart illustrating a search process according to a preferred embodiment of the invention.

Detailed Description of Preferred Embodiments

The monitoring, tracking and searching system, according to the specific preferred embodiments of the invention to be described below with reference to Figs. 1 - 15, consists of two basic units:

The monitored/searched unit - MSU; and

The monitoring and searching unit - SRU. This unit may also operate as an MSU.

-12-

Both units, according to the preferred embodiments described in the figures, have basically the same architecture, while the SRU includes additional special functions that enable it to perform the distance measuring and direction finding. As will be apparent to the skilled person from the following description, both MSU and SRU may be implemented in several configurations which fulfill specific requirements.

Referring now to Fig. 1, the MSU according to the specific preferred embodiment of the invention shown in the figures, comprises two basic sections: a digital section and a radio section. The digital section includes a microprocessing means 1 which consists of a processor, memories for storing program and data and I/O ports. Part of these I/O ports are connected to a display means 2, used to display messages, alarms, controls, etc., an audio means 3 used to reproduce prerecorded or synthesized audio messages through a small speaker 22 or similar device, alarms and other special sounds used for unit operation, a vibrator 4, to silently alert or notify the user about the occurrence of special events, and unit controls 5, used to enable the user to setup, operate and test the MSU. In addition the microprocessing means may exchange data with other electronic unit through a serial external interface 6. This microprocessing 1 means controls the overall operation of the MSU. It is driven by a clocks generation means 7 that generates all the clocks including those necessary for the synthesizer unit 8. The clocks generator unit 7 is controlled by the microprocessor 1 which is able to select different clock rates (e.g. to save power consumption,

-13-

change chip rates, center frequency, etc.). The microprocessor memories preferably consist of a ROM, EPROM or EEPROM for storing the unit software and a static RAM with standby mode and battery backup for storing data. Of course, any other type of memory, including flash memories, smart cards, magnetic cards, etc. may be used in combination with one or more of the mentioned memory types.

The radio section consists of the following units: a. an antenna or set of antennas 9, to receive and transmit data including an antenna selector 10 controlled 16 by the microprocessor 1, b. a T/R switch 11 used to connect the antenna input to the transmitter 12 or receiver 13 also controlled 16 by the microprocessor 1, c. a spread spectrum receiver 13 which receives modulated spread spectrum data and converts it to baseband data 14, generates a Received Data Signal Strength indicator 19 which is connected to the microprocessor 1 and is controlled by the microprocessor 1 via a control, clocks and status bus 20, d. a spread spectrum transmitter 12 which transmits the data generated by the data spreader 15 (a pseudo random noise generator) and is controlled by the microprocessor 1 via a control, clocks and status bus 20, e. A synthesizer unit 8 used to generate IF and RF frequencies which is controlled by the microprocessor 1 via a control, clocks and status bus 20, f. A correlator 17 also controlled by the microprocessor 1 through the same bus 20, used to correlate received spread spectrum data 14 with a known PN sequence. The correlating means 17 processes the I and Q signals 14 generated by the receiver 13 and synchronizes itself to the

-14-

received spreading sequence in order to perform two basic functions: a. Decoding of the spread spectrum received I and Q data 14 which is converted to the received data 18 which is also processed by the microprocessor 1. b. Generation of synchronization timing that enables the data spreader 15 to generate a spread spectrum message synchronized to the received message. Detailed description of the correlating means is shown in Fig. 6A and Fig. 6B. Transmitted data 21 is generated by the microprocessor and converted to spread spectrum data by the Direct Sequence Spreader 15. As may be seen from Fig. 1, the Control, Clocks and Status bus 20 interconnects between most of the MSU units enabling the distribution of clocks, timing, control and status signal among those units.

The MSU may use a single omnidirectional or directional antenna or a set of antennae 9 used to improve the reception in some environments where fading or other interference conditions exist. In those cases, the use of spatial diversity antennae significantly improve the receiver performance. The antenna or set of antennae may be internal (preferably a printed antenna) or it may be external, connected directly to the unit or mounted on a vehicle, etc. and connected to the unit via a cable. In some preferred embodiments the unit will be able to work with different types of antennae as previously described.

The MSU includes a battery and a DC-DC converter (not shown in the figure) used to supply the appropriate voltages to each of the MSU circuits.

-15-

The basic SRU is shown in Fig. 2 which has a similar architecture to the MSU shown in Fig. 1, and it includes all the additional functions required for the SRU operation. The SRU has the ability to use a directional antenna 31 which enables it to identify the approximate direction of an MSU transmitting a signal to that SRU. The basic SRU may use two types of antenna: a. an omnidirectional antenna for monitoring and b. when searching is required, the omnidirectional antenna is replaced by a directional antenna. In another preferred embodiment this single directional antenna is used for both monitoring and searching functions. In an additional preferred embodiment, the selection between those two antennas is done automatically by the SRU when the proper operation mode is selected. An additional embodiment (as shown in Fig. 3) includes an array of directional antennas 42 (preferably, but not limited to, between 3-8 elements 43,) and a selector 44 which selects each of those antennas or the combination of part of them or all of them (to create a wider antenna or omnidirectional antenna). This array of antennas is preferably implemented by printed antennas, which significantly simplifies the construction and reduces the cost. Similarly to the MSU, also this unit may use external antennae of many types, including retractable units or antenna units mounted on a vehicle, etc. and connected to the unit via a cable.

In addition, and referring to Fig. 2, the SRU includes a delay measurement circuit 32, which measures the time elapsed from the beginning of the first

-16-

transmitted sequence to the beginning of one or more of the received sequences. This delay measurement circuit is initialized and activated 34 by the spreading means 15 (indicating that the first sequence is being transmitted). For each valid Pseudo Noise (PN) sequence from the right ID that is received by the receiver correlator 17, the value of the delay is sampled (as schematically indicated by connecting line 33). Several sampled values may be averaged to improve the accuracy of the measured delay.

The SRU may at any time, operate as an MSU, and in that case, the time measurement function will not be used.

When operating, and referring to Fig. 2, the SRU transmits a signal that includes (among other information) a unique identifier of the MSU being monitored. This ID is specially coded into the spread spectrum signal in a way that improves significantly its detection by the MSU. The spread spectrum signal transmitted preferably includes a PN sequence for each transmitted data bit. The ID consists preferably of a 24 bit number enhanced by an 8 bit error correcting code. Each of the enhanced 32-bit ID code is used to modulate a PN sequence, while each "1" bit, inverts the PN sequence. If the MSU that receives this signal identifies itself, it transmits back a response signal with an identification unique to that MSU. When the SRU receives the MSU response it measures the elapsed time by comparing the value of an internal clock when the message was transmitted to the clock value when the response was received.

-17-

In another preferred embodiment of the invention and referring to Fig. 4, the SRU includes a smart card interface 50, allowing it to read and write information from/to plugged smart cards 51. Those smart cards 51, may contain, MSU or SRU ID's together with some additional parameters, as user description, communication parameters, user specific parameters, etc. Reading the smart card information, the SRU can monitor, track or search one or more of the read ID's. Information written into the card may include received messages, tracking history, status, etc.

As it will be apparent to the skilled person, also an MSU may include a smart card interface similar to the one described for the SRU.

In any of those embodiments, the SRU and MSU units can support setup functions via a serial interface that may be connected to a personal computer. Referring to Fig. 1-4, this serial interface 6 may, but not limited to, be electrical (RS-232 or similar) or infrared. This option allows immediate setup of units with complete backup and control of the programmed parameters. Setup is done using a friendly program, that guides the user how to program different system and unit parameters.

In another preferred embodiment, the SRU will include an interface to a bar code reader which can read small amounts of data including units ID's, user names, parameters, etc. This bar code reader will be preferably an internal bar code reader but it may be also an external reader, e.g. connected to the

-18-

serial interface 6, as shown in Fig. 1-4. When an external bar code reader is used, it will preferably receive its operating power from the SRU.

As was previously explained, both MSU and SRU units may support serial communication interface to several type of external units (including RS-232, infrared, etc.). Fig. 5, shows a special embodiment of the SRU (but it obviously can be applied to the MSU) which includes a PCMCIA interface 55 in order to allow their connection to laptops 56 or palmtop computers. In this preferred embodiment, the SRU or MSU are packaged according to PCMCIA standards which enables any portable computer to be used as an integral unit of the system. With the attached PCMCIA module, the computer operates exactly as an MSU or SRU stand alone unit. In a similar way, SRU or MSU units may be attached or integrated to many other electronic devices, including cellular telephones, radio transmission systems, car alarms, home alarms and other types of security systems, etc.

Fig 6 shows a block diagram of the MSU and SRU correlating means used to detect the spreading sequence received, identify the received ID, decode the received data and generate all synchronization timing required to transmit a synchronized pseudo random sequence. Referring to Fig. 6A, the MSU correlating means consists of Pseudo Random Sequence Matched Filter 62 used to correlate between the received data and a known pseudo random sequence, a message decoder 63 used to decode the received messages and generate a Received Data signal 68, an ID combiner 64, used to add the

-19-

pseudo random sequences in the right polarity according to the unit ID, an Envelope Detector 65 and a Signal Presence Detector 66 which generates the transmission synchronization timing 67 for the answer message. The Matched Filter 62 is fed from I 60 and Q 61 signals received from the RF section (not shown in this Figure) and preferably consists of a parallel correlator of a complete pseudo random sequence. All the blocks described, are controlled by the MSU microprocessor (not shown in this Figure).

Referring to Fig. 6B, the SRU correlator includes basically the same blocks as the MSU correlator (Fig. 6A), but preferably includes additional logic required to identify and process multipath signals. The I 69 and Q 70 signals are correlated by the Matched Filter 71 and combined by the ID Combiner 78. The output I and Q signals from the ID combiner 78 are fed to three sampling circuits: Path # -1 Sampling 72, Path # 0 Sampling 73 and Path # 1 Sampling 74. The same I and Q signals are fed to a Multipath Detection and Estimation means 75 which controls 76 the sampling circuits 72-74 and specifies the timing at which each of these circuits samples the I and Q signals. Optimal results are received by combining the I and Q output of each of the sampling circuits in a Path Combiner/Selector 79. A Timing Detection and Estimation means 80 uses the Path Combiner/Selector 79 output to provide the timing of the received message. The SRU microprocessor (not shown in this Figure) performs the control of all the correlating circuits. Received messages are decoded by the Message Decoder

-20-

77 which generates a Received Data signal 81 connected to the microprocessor.

The SRU preferably adapts its operating parameters according to the unit being monitored, to the communication channel quality and other parameters. For example, the SRU is able to perform, and not limited to, an average of 10-100 distance measures per second (600-6000 measures per minute) but with the possibility to change the time between two consecutive measures according to the application, channel load, distance from the object (measure interval may be adapted to the distance, while far objects are monitored more frequently than close objects), user setup, etc. In respect to the object distance, the monitoring process is much more effective, giving special attention to units likely to be outside the programmed range.

The monitoring interval period of a specific MSU will be preferably in the range of 30-600 seconds. In search mode, this frequency may preferably increase to 5-100 measures per second. In addition the user is able at any time, to initiate a distance measure to a single or group of MSU's. Moreover, the SRU may change the spreading chip rate, data rate, PN sequence length, transmitting power and other parameters according to the distance from the MSU and the communication link quality.

Distance measuring uses preferably an averaging filter, which may be software or hardware implemented, to smooth the effects of errors

-21-

(according to the measuring interval) and in addition, both the SRU and MSU perform a multipath elimination or reduction by analyzing the quality, the direction (for units equipped with directional antenna), the strength and the time of arrival of the received signal. An additional distance measurement improvement may also be achieved by estimating the position of the theoretical correlation peak, preferably using algorithms that fit the actual correlation values to a mathematical function.

The stand-alone embodiment of the MSU or SRU and according to the preferred embodiment of Fig. 7, comprises of a small case 100 preferably of rectangular shape, that is easily carried by a person on his belt, pocket, etc., and including any means for attaching or securing this case to the belt or pocket, preferably a spring clip on the back of the unit (not shown in Fig. 7). It also comprises of an alphanumeric display 101, used to display: received messages, sent messages, status information, operation menus, control data, advertisement data, etc., an emergency push-button 102, used to transmit an emergency call message or any other type of message as previously programmed or selected, a small speaker or buzzer 103, used to reproduce audio alarms, messages or control/status signals (e.g. during search process, or when out of coverage, etc.), a keypad 104 comprising of a number of keys to be used for the unit operation and an indicator 105 used for different acknowledgement and status purposes during the unit operation. Of course, the user may program or select, which of the audio signals, if any, he desires to hear. In addition, the alphanumeric display,

-22-

has an optional back-light which improves the reading capabilities at low light conditions. The unit is turned ON and OFF preferably by a small slide key (not shown in the figure) but it has mechanisms to save battery power, by shutting off the display and other unit functions. The unit has an antenna, preferably an integrated antenna, inside the unit, but in some preferred embodiments, an external antenna may be pulled out from the unit or connected to the unit through an external connector. The unit is operated from standard batteries, easily replaced by a non-skilled operator. A low battery indication, warns the operator about low battery condition. A variation of this preferred embodiment may include a smart card interface and means for inserting the card into the unit.

A different preferred embodiment, more suitable for the MSU, and illustrated in Fig. 8, comprises of a watch-style case 110 attached to a strap 111 for securing the unit to the user's hand or leg. The unit functions are similar to those described in Fig. 7, and include an alphanumeric display 112, status indicators 113, acknowledgment and status indicator 114, unit controls 115, emergency push-button 116 and an optional watch display 117. The unit is preferably made of plastic, preferably with an average diameter of 2 inches and includes an internal antenna and a small battery compartment.

Fig. 9 shows an additional preferred embodiment more suitable for the SRU. It comprises of a hand-held unit 121, comprising a case body 122 and a cover

-23-

123 electrically connected to the said body. The body comprises of an alphanumeric and graphic display 124, used to display received messages, sent messages, status information, operation menus, control data, direction indications, advertising data, etc., an ESCAPE key 125, a SEND key 126, a MODE key 127 and four arrow keys 128, used to operate and perform all the unit functions, a small speaker or buzzer 129, used to reproduce audio alarms, messages or control/status signals (e.g. during search process, or when out of coverage, etc.), a ON/OFF switch 130 to turn on and off the unit, a serial interface connector 131, used to connect external units for setup, report, combined operation, etc. and a belt clip 132, used to secure the unit to a belt or pocket when carried by a person. As in other embodiments, the user may program or select, which of the audio signals, if any, he desires to hear and the alphanumeric display, has an optional back-light which improves the reading capabilities at low light conditions. Of course, this unit may also include a smart card interface and means for enabling insertion of the card into the unit. The cover 123 includes a built-in array of directional antennae used to detect the direction of the received message. When the user desires to find the direction to a monitored or searched MSU, he opens the cover to an horizontal position, and the display 133 will show the direction.

To better understand how the direction is displayed and referring to Fig. 10, the SRU display provided in accordance with a preferred embodiment of the invention, includes a star-shape graphic direction indicator 141. This

-24-

indicator has a number of pointing indicators 142 equal to the number of antenna elements embedded in the SRU cover. For example, in Fig. 10 the number of such pointing indicators 142 is five. When a message is received, the SRU displays the direction and the quality of the reception by illuminating the corresponding pointing indicator. The reception quality is shown by the proportional illumination of part 143 or all the pointing indicator. While no illumination represents NR - NO RECEPTION 144, partial illumination represents VPQ - VERY POOR QUALITY 145, LQ - LOW QUALITY 146, MQ - MEDIUM QUALITY 147 and GQ - GOOD QUALITY 148, and complete illumination represents EQ - EXCELLENT QUALITY 149. This direction indicator is only a preferred embodiment, but many others direction indicators may be used without exceeding the scope of this invention. Another preferred embodiment will include an integrated mechanical or electronic compass, allowing the unit to align its direction indicators referenced to absolute directions and also calculate the azimuth of the measured direction. This calculated azimuth may also be transmitted to other units and used as a reference to improve the searching process.

As it was explained, and with reference to Fig. 9, the unit has an antenna, preferably an integrated antenna, inside the unit cover, but in some preferred embodiments, an external antenna may be pulled out from the unit or connected to the unit through an external connector. The unit is operated from standard batteries, easily replaced by a non-skilled operator. A low battery indication, warns the operator about low battery condition.

-25-

As previously explained, range calculation is performed by calculating the elapsed time between the starting time of a transmitted signal to the starting time of one or more synchronized received signals. Referring to Fig. 11, the transmitted signal - TS 151, includes n pseudo random sequences, nominated $S\#1$ to $S\#n$. The number of sequences is not fixed (preferably between 10-40) and is adapted to several link parameters in order to improve both communication quality and channel utilization. The chip rate and length of each pseudo random sequence is also variable and adapted to operational parameters. A time stamp of the starting of $S\#1$ in the transmitted signal 151, is kept in the transmitter. When a signal is received 152 and a correlation with the same pseudo random sequence is found on any sequence (not necessarily on the first one), the elapsed time is calculated as follows:

Elapsed Time = Time Stamp of Received Signal Correlation - Time Stamp of T_0 .

The elapsed time is measured in clock units, being the clock, the chip rate clock.

If, for example, in a preferred embodiment, the chip rate is 20 MHz, and the difference as calculated above is 5700 pulses, it means that the time elapsed is: $5700 \times 50 \text{ nsec} = 285 \text{ usec}$.

-26-

The actual delay time between the TS and RS is calculated as follows:

$$\text{Delay} = \text{Elapsed Time} - n * \text{SL}$$

whereas:

SL - Sequence Length = Number of chips x Chip duration

n - an integer number, calculated as the highest integer where the following equation is true:

$$\text{Elapsed Time} > n * \text{TS}$$

The range between the units is calculated by converting the delay time to the distance traveled by light during this time and dividing it by two.

As should be understood by the skilled person, it is possible to improve the measured distance accuracy, by estimating the theoretical position of the correlation peak of the received signal (at each side). Using appropriate algorithms (e.g., fitting the actual correlation function to a mathematical function and then using the mathematical function peak as the real peak), it is possible to reduce this error to a small percentage of the chip duration.

Both SRU and MSU units have the optional capability of transmitting and receiving frequency hopping signals. Frequency hopping are used in conjunction with direct sequence spreading. When used together, the system has a higher degree of robustness due to its capability to overcome most of the interference found in unlicensed bands including near/far problems.

-27-

Referring to Fig. 12, the SRU calls the MSU with a Call Message - CM U#1-165 at a predefined frequency, and the MSU responds sequentially, with an Answer Message (AM) at four different frequencies 166-169. The number and the value of the frequencies are system parameters and may be predefined or dynamically defined by the SRU, when transmitting its Call Message (CM). A Call Message from a different unit 170 is sent to a different MSU and it responds with four Answer Messages at a different set of frequencies 171-174. That permits the SRU to adapt itself to the environment and select frequencies where the best results are achieved. In addition, it reduces the mutual interference between two similar units operating independently at a distance where each is interfered by the other.

Referring now to Fig. 13, the proposed system may be configured differently according the specific application ranging from a very basic system consisting of one SRU 180 and few MSU's 182-183, to a much more complex configuration, including many SRU's 180-181 and MSU's 182-185. Each SRU maintains continuous communication with all monitored MSU's and measures the distance to each of the units. In parallel, it opens its receiver to allow reception of a message from any of the MSU's.

As previously explained, the SRU measures the distance to each of the monitored MSU's and compares this distance to a pre-programmed distance range. If the distance to one or more of the MSU's is outside (smaller or greater than) the pre-programmed distance range for that MSU, the SRU

-28-

may notify the user, indicating that this specific MSU is outside the pre-programmed distance range. In response to this event, the SRU may send a message to the monitored MSU notifying the user, that he is outside the pre-programmed distance range. The message may include the measured distance that will be displayed to the MSU user. The value of the measured distance is compared to previous readings in order to discard erroneous measurements.

The monitoring process, may start automatically or manually after MSU's are logged in. The SRU user may setup different parameters for the monitoring of each MSU or group of MSU's, or use the system default values. Illustrative, but not limitative, parameters that may be defined are:

- Monitoring priority
- Monitoring interval
- Distance range
- Storing of monitoring events history.
- Type of MSU and SRU notification
- Messaging options

As will be understood by the skilled person, the monitoring process performs all its monitoring functions keeping the communication channel as free as possible. As previously explained, this is achieved by adapting the communication and monitoring parameters to the channel quality and monitoring task.

-29-

In some cases, where a constant monitoring is not required, and the monitored unit does not need to listen the communication channel periodically, it is possible to reduce significantly the channel traffic and the MSU power consumption by limiting the monitoring to be passive. This means, that each MSU, will be programmed to send a monitoring request to the SRU at programmed intervals (preferably from seconds to several hours).

The MSU is normally in standby mode, and only as a result of an MSU event or at pre-programmed times, it will communicate with the SRU and request a monitoring operation. Pre-programmed events may for instance be the result of:

- Internal events

1. Interval timer
2. Time of Day clock
3. Battery status.
4. Programmed events.
5. Turning the unit ON or OFF.
6. Internal sensors

- External events

1. Serial communication messages
2. External sensors (e.g. shock, position, etc.)

-30-

3. Analog sensors

4. Digital inputs

As a result of this monitoring operation either the SRU or MSU may initiate an activity. For example, if the MSU is out of the permitted range, it can enter into normal mode and allow the SRU to search it.

This mode is very useful, for applications where the monitoring of objects is required. The SRU will periodically or upon request, prepare a report including the status of all monitored units and the event that triggered each monitoring action.

The SRU may also notify the user when an expected passive monitoring action from a specific MSU is not performed within a programmed time period from the previous monitoring action.

The SRU user has the option to start a search operation in order to find a monitored MSU. The searched MSU user may be notified that he is being searched, allowing him, in some cases, to cooperate with the search process. In addition, the MSU may be continuously notified that the SRU is becoming closer.

SRU or MSU user notifications about the search process progress may be effected in several ways, for instance:

-31-

Audible notification: A variable frequency or loudness beep may indicate if the SRU is approaching or moving away from the MSU (or indicate its distance from the MSU). The user may hear the beep preferably using headphones or a small integrated speaker or buzzer.

Visual notification: Color LED's will indicate if the SRU is approaching or not to the MSU. In addition, some SRU's or MSU's may include an alphanumeric, numeric or analog display indicating the measured distance.

Normally, the search result indicators will be set according to an internal algorithm that will process the distance measured. In a preferred embodiment, each new measurement is weight-averaged with previous measurements, taking in account the time elapsed from the current measurement, the received signal quality of each measurement, the measured direction (if applicable), multipath conditions and measured distance. In principle, this algorithm performs a moving average process where recent measurements have a higher weight. Algorithm parameters are changed dynamically in order to adapt the smoothing process to the channel conditions and to the distance changing rate. In addition erroneous measurements caused by low quality reception or strong multi-paths, are discarded. This internal algorithm reduces user confusion and improves the

-32-

system performance, specially in problematic areas or under difficult communication channel conditions.

During the search process, and in order to improve this process, the SRU has the option to continuously measure the distance and direction only to the searched MSU.

According to a preferred embodiment where there is a single directional antenna, the SRU user is able to move the unit to different directions and process the received signal (based on the signal strength and other parameters), thus giving an indication of the direction to the MSU. According to a second preferred embodiment, as shown in Fig. 9, the SRU includes a set of directional antennas that may be selected by the microprocessor. In this embodiment, the processor will receive signals from each of the antennas and process them. The MSU direction will be displayed in a special display (see Fig. 10) indicating the direction and signal quality.

The search operating mode will be normally initiated by the SRU user in order to find the location of a specific MSU. However, it is possible to start a search process, as follows:

Automatically: The SRU will enter into this mode after an abnormal event (if programmed). During the search process, the SRU may continue monitoring other units.

MSU request: Some of the MSU's may request a passive SRU search, what means that the SRU will continue performing all its other functions, but to the MSU that requested the search, the SRU will transfer processed data that will enable the MSU user to find the SRU (opposite to the normal situation).

The passive search process may be performed simultaneously to several MSU's.

The SRU or MSU is able to store the distance measured at a reference point and later compare a new measurement to this reference point. In some difficult cases, when the normal indicators cannot clearly show if the search process is converging, the user may store the measured distance at a known point and after he has moved a significant distance, make a distance compare. If the distance is shorter, the user will be notified and the new point will be kept as a reference for the next compare. The distance between the units, for reference purposes, will be calculated from several readings in order to have a more reliable measuring. For history use, the MSU or SRU may keep the distance readings in each of the reference points.

Referring to Fig. 15, a Search process 220 may be started automatically triggered by an event or manually initiated by the SRU user. When the Search process is initiated, the initial parameters are set 221, including search mode, communication parameters, search interval, alert/notification

-34-

options, event history recording options and other setup parameters. According to those parameters, the SRU transmits a search message 223 and waits for a response 225. If no answer is received 227, the SRU checks if the number of retries programmed was exceeded 226. Exceeding this limit means that communication with the searched unit has failed and an acquisition process shall be performed 228 (refer to Fig. 14 for further details). If the number of retries 226 was not exceeded, the SRU will preferably modify part of the communication parameters 224 in order to achieve better communication with the searched unit. Then the number of retries performed is incremented by one 222. When a response is received, the SRU analyzes its quality 230 and if acceptable process the answer 232. Otherwise, the SRU will preferably modify part of the search parameters 231 and a new message will be transmitted. For example, the received message at different frequencies is analyzed and search parameters are modified according to previous and current results. In addition, quality thresholds are also preferably adapted to the actual communication quality. After processing the answer 232, the search process will continue if the search flag is active 233 and then, search parameters are updated 234 (according to measured distance, priority, etc.), indicators are set and if required messages are transmitted including the search results. If the search flag is not active, the search process is completed 235. This flowchart is for explanatory purposes only and for obvious reasons it does not include all the specific constructional details found in the complete flowcharts of each of the different embodiments.

As previously described, at any time, may any of the monitored MSU's send a message (emergency, control, etc.) to the SRU and in response the SRU will send an acknowledge to the MSU. Obviously, the SRU may also send, at any time, a message to a single, group or all monitored MSU's.

In some cases, where there is no communication link between the SRU and MSU, the SRU may initiate an acquisition process intended to establish link with a specific unit or group of units. The acquisition process takes place by transmitting call signals to the called unit or units. If no response or poor quality is received, the SRU will modify some of the channel parameters in order to achieve better results. When the acquisition process is completed, the user is notified by any of the audio-visual indicators. If defined by the SRU user, also the MSU user will be notified that his unit was acquired by an SRU.

Referring to Fig. 14, an Acquisition process 200 is started in order to establish first communication with a unit. After the Acquisition process is initiated, the initial communication parameters are set 201, including transmission power, link frequencies, chip rate, antenna used, etc. According to these parameters, the SRU transmits a call message 203 and waits for a response 205. If no answer is received 207, the SRU checks if the number of retries programmed was exceeded 206. Exceeding this limit means that communication with the called unit has failed 208 and the user

-36-

shall be notified. If the number of retries 206 was not exceeded, the SRU will preferably modify part of the communication parameters 204 in order to achieve better communication with the called unit. Then the number of retries performed is incremented by one 202. When a response is received, the SRU analyzes its quality 211 and if it is acceptable, it processes the answer 212. Otherwise, the SRU will preferably modify part of the communication parameters 210 and a new call message will be transmitted. For example, as previously explained for the search process, the received message at different frequencies is analyzed and communication parameters are modified according to previous and current results. In addition, quality thresholds are also preferably adapted to the actual communication quality. After processing the answer 212, the acquisition process is completed 213. This flowchart is for explanatory purposes only and for obvious reasons it does not include all the details found in the complete flowcharts found in the different embodiments.

Beside the basic functions of distance measurement and direction finding, the system described in this invention inherently supports a wide variety of functions intended for different applications or uses. As will be apparent to the skilled person, the same communication channel used for distance measuring may be used for two-way communication between any two units (MSU-MSU, SRU-SRU and MSU-SRU). The following is a list of the main types of messages that are used by the system, according to a particular embodiment of the invention:

-37-

| Type | From/To | Contents | Comments |
|-------------------------|--------------------------------|-----------------------|--|
| Emergency | MSU to SRU | Emergency Code | Used to alert the tracking SRU(s) about an abnormal event at the monitored MSU |
| Control | SRU to MSU | Control Commands | Used to control the MSU from the SRU. For example: Set/Reset alarm Set/Reset LED's Transmission power |
| Data | SRU/MSU to SRU/MSU | Short data message | Used to transfer a free text or binary message between the units. For example: User messages Measured distance Relay data Synthesized voice messages (only a code will be transmitted). Advertisement messages. |
| Setup/ Configuration | SRU to MSU MSU to SRU | Setup data | Log-in/Log-out Time-outs Addresses H/W Configuration |
| Test | SRU to MSU or MSU to SRU | Test data | |

All messages include preferably destination and sender description as well as error correction codes adapted to the channel used. All non-broadcast messages are preferably acknowledged in order to ensure that messages are

-38-

properly received. Non-received messages or uncorrectable messages are preferably retried. For some type of messages a manual acknowledge of the user is requested in addition to the automatic system acknowledge. Manual acknowledge is preferably performed by pressing the panic button or any other button specified for that purpose. This feature allows the message sender to verify that the message sent was received by the user. Messages are preferably canned messages, where only a message code is sent, but for many applications they may be free text messages (e.g. ASCII coded) with or without encryption (using encryption improves privacy and security). Received messages may also be used to control output lines and unit functions. If previously setup, a message may also be sent as a result of an MSU being turned OFF (the message is sent before the unit is turned OFF) or when the unit is turned ON.

Messages are typically displayed on an alphanumeric display, although they can be provided in other forms, e.g., audible form. In most of the cases, only the message code is transmitted, while the unit receiving the message code, displays the complete message or activates an audio visual indicator. In some cases, a mechanical vibrator is used to notify the user that a message was received.

In another preferred embodiment, the message code is used to generate a voice message (using an internal voice synthesizer). This voice message is very effective when the unit is carried by young children, elderly and

-39-

disabled people or in situations where the user is not free to read a displayed message.

In other preferred embodiments, also a voice recognition function is added, allowing people to send emergency messages or any other messages without any button handling.

The setup of each unit in the system is based on default parameters programmed during or after the manufacturing process. The user is able to modify part of those parameters in order to adapt the unit to his special requirements and applications.

MSU units have a simple setup, while SRU units allow the user to specify monitoring, tracking, searching and messaging parameters. In addition, each SRU may be setup to operate as an MSU (in conjunction with its SRU functions). The SRU has the capability to remote setup an MSU using Setup/Configuration messages.

One of the most important tasks to be performed during setup is addition of new MSU's to the monitoring list. This process is done very easily, by entering the SRU unit to a log-in mode and activating the MSU. This log-in process will read the MSU address and verify communication parameters with this MSU. In addition the SRU address will be kept in the MSU and marked as an active monitoring SRU.

As previously explained, one MSU may be monitored by several SRU's and in that case, the MSU will have a list of all active SRU's. After the log-in

-40-

process with a specific MSU is completed, both units will enter into the monitoring mode or as programmed. In addition to the MSU address, the MSU will transmit a user identification (name, place, etc.) that will enable the SRU user to easily identify each of the MSU users.

Log-out of unmonitored units may be performed manually or automatically after a pre-programmed time, without communication between the units.

Testing of the system is performed as a routine operation, during units setup and also during normal operation. In addition, a user is able to test his unit or a complete system, at any time, according to system restrictions.

Testing includes, but is not limited to, one or more of the following:

- H/W performance
- Battery status
- Communication with other units.
- Validity of stored data

Both SRU and MSU units are designed to allow some degree of fault-tolerance, according to the application and cost limitations.

According to an additional preferred embodiment of the invention, the user of the SRU is able to program sophisticated monitoring, tracking and searching functions, combining all the system and units capabilities. The user is able to store different such programs intended for different

-41-

applications or situations. Selection of one of those programs is done easily using the control panel. For example the SRU may automatically initiate different monitoring functions or send messages to a single or group of persons according to the Time-of-Day clock, programmed inputs, etc..

Network operation, and referring to Fig. 13, enhances the system monitoring, tracking and searching capabilities, by allowing the following functions:

- One MSU 183 may be monitored and searched by several SRU 180-181 units;

- SRU's 180-181 are able to share monitoring, tracking and searching data, by transmitting this information each to other either directly or via other wireless communication channels 186;

- Transfer of the above information, from several SRU's, to a center 187 including graphic capabilities. This feature allows the system to approximately locate a unit, by analyzing the distances from each SRU (at reference points) to the searched MSU;

- Execution of monitoring, tracking or searching operations when requested by another SRU. This option allows one SRU that for any reason (e.g. distance) cannot contact a monitored MSU, to request from a neighbor SRU to perform a monitoring, message transfer or search operation and transfer the results to the requested SRU. This relay function increases the

-42-

effective range units can be monitored or searched and the system reliability.

In a network operation, each SRU plays a role of master or slave SRU and according to its configuration it will be permitted to perform different system functions. In addition, MSU or SRU units may be used to broadcast information to other units, thus enhancing the system coverage and message transfer reliability.

For more sophisticated applications, the network operation may include the use of Ground Positioning System (GPS) receivers to allow each SRU to locate itself with a high precision and maintain a common and synchronized clock. As previously explained, also a mechanical or electronic compass may be integrated, thus upgrading the SRU to have the capability to calculate azimuths.

In this network operation, two or more SRU's equipped with such GPS receivers, enable to calculate the actual position of the searched unit (the accuracy is increased when more SRU's are used), using the measured range from each SRU to the MSU and their absolute position (calculated using the GPS). In some cases, azimuth indication may help to resolve ambiguities.

As previously explained and referring to Figs 7-9, the units of the system include several indicators to alert the user about the occurrence of special events or to show the results of some of the unit functions. An alphanumeric

-43-

display is used to display alphanumeric data necessary for the operation of the unit. Following a list of typical items to be displayed:

- Transmitted messages;
- Received messages;
- Distances measured;
- Errors and test results;
- Setup parameters;
- Menu options;
- Battery condition.
- Advertising information

The typical display as shown in Figs. 7 and 9, preferably includes 2-4 rows of 20 characters each. This display is preferably included in the SRU units. MSU units preferably include a smaller one-row display.

Some of the unit functions activate color indicators or special icons on the display. The illustrative and non-limitative examples of such indicators include:

- Unit malfunction;
- Low battery;
- MSU being searched;

-44-

- Measured distance is shorter than the previous measurement;
- Measured distance is longer than the previous measurement;
- No communication link with an SRU.

Audio indicators are intended to alert the user about unexpected events or give him information in a way that do not require visual attention (very useful during search). Following an illustrative and non limitative list of some of the events that may trigger an audio alarm or indicator:

- Unit malfunction;
- Low battery;
- MSU being searched;
- Measured distance is shorter than the previous measurement;
- Measured distance is longer than the previous measurement;
- MSU out of programmed range;
- No communication link with a SRU.

The audio indicator(s) may, but is not limited to, be a buzzer capable to sound different types of chirps, speaker, headphones, etc..

Most of the units functions are controlled by single function keys or menu driven keys. Another preferred embodiments will include a numeric or alphanumeric keyboard incorporated to support more sophisticated unit functions.

-45-

Referring to Figs 1-4, all system units may be used in a stand-alone mode without the necessity to attach an external unit. However, the attachment of external units or their integration with an MSU or SRU, as shown for example in Fig. 5 (personal computer, portable computer, wireless communication equipment, any kind of alarms, toys, etc.) may enhance the system capabilities and open a wide range of uses. In addition, special purpose sensors (e.g. biomedical sensors, vending machines sensors, security sensors, etc.) may be attached and enhance the system capabilities. Due to the fact that there are many possible interfaces that may be used and their use depends on the specific application and equipment used, no specific description is given herein of interfaces that each unit will support, and such interfaces will be easily recognized by the skilled person.

All the above description of preferred embodiments has been provided for the purpose of illustration, and is not intended to limit the invention in any way. Many modifications can be effected in the construction of the various units, many interfaces can be provided, and many functions can be incorporated in the devices of the invention, all without exceeding the scope of the invention.

-46-

CLAIMS:

1. A combined portable monitoring, tracking and searching system, comprising one or more monitored and/or searched units (MSU) and one or more monitoring and searching units (SRU), wherein:

- the MSU comprises processing means, memory means, display and/or audio means, a transmitting/receiving antenna, a spread spectrum receiver to receive modulated spread spectrum data and to convert it to baseband data, a spread spectrum transmitter, a data spreader, a synthesizer or frequency generator, and a correlator to correlate spread spectrum data received by said spread spectrum receiver with a known Pseudo Noise (PN) sequence;

- the SRU comprises processing means, memory means, display and/or audio means, a transmitting/receiving omnidirectional antenna, a transmitting/receiving directional antenna, a spread spectrum receiver to receive modulated spread spectrum data and to convert it to baseband data, a spread spectrum transmitter, a data spreader, a synthesizer unit or frequency generator, a correlator to correlate spread spectrum data received by said spread spectrum receiver with a known PN sequence, and delay measurement means, to measure the time elapsed from the beginning of a first transmitted sequence to the beginning of one or more of the sequences received from an MSU in response to said first transmitted sequence.

-47-

2. A system according to claim 1, wherein the SRU comprises means for identifying and logging-in each MSU into the system.
3. A system according to claim 1 or 2, wherein one SRU monitors a plurality of MSU's.
4. A system according to any one of claims 1 to 3, wherein two or more SRU's are present in the system, and wherein each MSU may log-in to two or more such SRU's.
5. A system according to any one of claims 1 to 4, wherein each SRU includes a single directional antenna.
6. A system according to any one of claims 1 to 4, wherein each SRU includes an omnidirectional antenna and a directional antenna, and wherein each SRU comprises means for selecting which antenna to operate at a given time.
7. A system according to any one of claims 1 to 4, wherein each SRU includes an array of directional antennae and comprises means for selecting which antenna of the said set or combination thereof to operate at a given time.

-48-

8. A system according to any one of claims 1 to 7, wherein the SRU and/or the MSU include a diversity antenna.
9. A system according to any one of claims 1 to 8, wherein each SRU and/or MSU is able to send and receive messages to or from one or more such units.
10. A system according to claim 9 further comprising means for encrypting and decrypting transmitted and received messages, respectively.
11. A system according to claim 9 or 10, wherein the SRU and/or the MSU comprise means for generating messages suitable to enable remote setup and/or control of other units.
12. A system according to any one of claims 9 to 11, comprising error correction means for protecting messages by error correction codes.
13. A system according to any one of claims 9 to 12, comprising an SRU and/or an MSU, each of which may independently comprise means for generating synthesized voice messages using received messages.
14. A system according to any one of claims 1 to 13, wherein the SRU and/or the MSU comprise voice recognition means.

-49-

15.A system according to any one of claims 1 to 14, wherein the SRU comprises a bar-code reader or bar-code reader interface.

16.A system according to any one of claims 1 to 15, wherein the SRU and/or the MSU comprise a smart card reader.

17.A system according to any one of claims 1 to 16, wherein the SRU and/or the MSU comprise a PCMCIA interface and/or serial interface.

18.A system according to any one of claims 1 to 17, comprising analog or digital I/O lines for sensing external events or interfacing to external sensors and/or activating external units or circuits, provided within the SRU and/or the MSU.

19.A system according to any one of claims 1 to 18, wherein the SRU and/or the MSU comprise a GPS receiver.

20.A system according to any one of claims 1 to 19, wherein the SRU and/or the MSU comprise mechanical or electronic compass means.

21.A unit suitable for use in a monitoring, tracking and searching system, comprising processing means, memory means, display and/or audio means, a transmitting/receiving antenna, a spread spectrum receiver to

-50-

receive modulated spread spectrum data and to convert it to baseband data, a spread spectrum transmitter, a data spreader, a synthesizer unit, and a correlating means to correlate spread spectrum data received by said spread spectrum receiver with a known PN sequence.

22.A unit according to claim 21, comprising means for storing preset messages and means for broadcasting a message selected from among said preset messages to a specific similar unit or to a plurality of units.

23.A unit according to claim 22, wherein the message is a message that can be displayed on display means.

24.A unit according to claim 22, wherein the message is an audio message.

25.A unit according to claim 22, comprising means for actuating a remote device using the contents of the message.

26.A unit according to claim 22, comprising means for activating a vibrator located within the unit using the contents of the message.

27.A unit according to any one of claims 1 to 26, comprising logic means for selecting a message to be broadcasted in response to a message received from another unit.

-51-

28.A unit according to any one of claims 1 to 27, which is an MSU.

29.A unit according to any one of claims 1 to 27, which is an SRU.

30.A unit according to claim 21, comprising processing means, memory means, display and/or audio means, a transmitting/receiving antenna, a directional antenna, a spread spectrum receiver to receive modulated spread spectrum data and to convert it to baseband data, a spread spectrum transmitter, a synthesizer unit or frequency generator, a correlator to correlate spread spectrum data received by said spread spectrum receiver with a known PN sequence, and delay measurement circuitry, to measure the time elapsed from the beginning of a first transmitted sequence to the beginning of one or more of the sequences received from an MSU in response to said first transmitted sequence.

31.A unit according to claim 30, wherein the omnidirectional antenna and the directional antenna are interchangeable.

32.A unit according to claim 30, wherein the omnidirectional antenna and the directional antenna are integral with the unit, and switching means are provided to switch between them.

-52-

33.A method for monitoring and/or searching and/or locating a subject provided with a unit according to claim 5, comprising measuring the distance to one or more monitored units using a spread spectrum ranging method, and/or using logic means to perform preprogrammed activities as a function of the measured distance, and optionally, by determining the direction of the searched unit using a directional antenna.

34.A method for searching and locating a subject provided with a unit according to claim 21, wherein the measured distance is used to activate a visual and/or audio indicator that enables the user to understand if his distance from the searched unit is increasing or decreasing.

35.A method according to claim 33 or 34, wherein the measured distance is displayed in a numeric, and/or alphanumeric and/or analog display.

36.A method according to any one of claims 33 to 35, further comprising transmitting the measured distance also to the monitored unit, and displaying the measured distance in the monitored unit and/or using logic circuitry to perform preprogrammed activities as a function of the measured distance.

37.A method for searching and locating a subject provided with a unit according to claim 21, wherein the measured direction is used to activate

-53-

a visual indicator that enables the user to know the direction of the received signal from the searched unit.

38.A method according to any one of claims 33 to 37, wherein the measured direction is displayed in a graphic and/or analog display.

39.A method according to claim 38, further comprising relaying distance, direction and other information of the searched unit to additional units.

40.A method for the combined monitoring, tracking and searching of objects, persons or animals, comprising providing one or more monitored and/or searched units (MSU) and one or more monitoring and searching units (SRU), wherein:

- the MSU comprises processing means, memory means, display and/or audio means, a transmitting/receiving antenna, a spread spectrum receiver to receive modulated spread spectrum data and to convert it to baseband data, a spread spectrum transmitter, a data spreader, a synthesizer or frequency generator, and a correlator to correlate spread spectrum data received by said spread spectrum receiver with a known PN sequence;

- the SRU comprises processing means, memory means, display and/or audio means, a transmitting/receiving omnidirectional antenna, a transmitting/receiving directional antenna, a spread spectrum receiver to receive modulated spread spectrum data and to convert it to baseband

-54-

data, a spread spectrum transmitter, a data spreader, a synthesizer unit or frequency generator, a correlator to correlate spread spectrum data received by said spread spectrum receiver with a known PN sequence, and delay measurement means, to measure the time elapsed from the beginning of a first transmitted sequence to the beginning of one or more of the sequences received from an MSU in response to said first transmitted sequence; and monitoring the distance and/or the direction of each of said MSU's by one or more of said SRU's.

41.A method according to claim 40, wherein the SRU comprises means for identifying and logging-in each MSU into the system.

42.A method according to claim 40 or 41, wherein one SRU monitors a plurality of MSU's.

43.A method according to any one of claims 40 to 42, wherein two or more SRUs are present in the system, and wherein each MSU may log-in to two or more such SRUs.

44.A method according to any one of claims 40 to 43, wherein each SRU includes a single directional antenna.

45.A method according to any one of claims 40 to 43, wherein each SRU includes a single omnidirectional antenna.

-55-

46.A method according to any one of claims 40 to 43, comprising providing in each SRU an omnidirectional antenna and a directional antenna, and selecting which antenna to operate at any given time.

47.A method according to any one of claims 40 to 43, comprising providing in each SRU an array of directional antennae and selecting which antenna of the said set or combination thereof to operate at any given time.

48.A method according to any one of claims 40 to 47, wherein the SRU and/or the MSU include a diversity antenna.

49. A method according to any one of claims 40 to 48, wherein each SRU and/or MSU is able to send and receive messages to or from one or more such units.

50. A method according to claim 49 transmitted and received messages, are encrypted and decrypted, respectively.

51. A method according to claims 49 or 50, wherein the SRU and/or the MSU generate messages suitable to enable remote setup and/or control of other units.

-56-

52. A method according to any one of claims 49 to 51, comprising protecting messages by error correction codes.
53. A method according to any one of claims 49 to 52, comprising generating synthesized voice messages using received messages.
54. A method according to any one of claims 40 to 53, wherein the SRU and/or the MSU comprise voice recognition means.
55. A method according to any one of claims 40 to 53, wherein the SRU comprises a bar-code reader or bar code reader interface.
56. A method according to any one of claims 40 to 55, wherein the SRU and/or the MSU comprise a smart card reader.
57. A method according to any one of claims 40 to 56, wherein the SRU and/or the MSU comprise a PCMCIA interface and/or serial interface.
58. A method according to any one of claims 40 to 57, wherein the SRU and/or the MSU comprise analog or digital I/O lines for sensing external events or interfacing to external sensors and/or activating external units or circuits.

-57-

59. A method according to any one of claims 40 to 58, wherein the SRU and/or the MSU comprise a GPS receiver.
60. A method according to any one of claims 40 to 58, wherein two or more SRU's equipped with GPS are used to locate an MSU.
61. A method according to any one of claims 40 to 60, wherein the SRU and/or the MSU comprise a mechanical or electronic compass means.
62. A method according for combined monitoring, tracking and searching, comprising searching an SRU by means of an MSU, based on the information received from the said SRU.
63. A system according to any one of claims 1 to 20, wherein three or more units are networked so as to be provided with means to exchange data between them.
64. A method according to any one of claims 33 to 62, wherein two or more units cooperate in the monitoring, and/or searching and/or locating of a third unit.

-58-

65. A method for the combined monitoring, tracking and searching of objects, persons or animals, substantially as described and illustrated, and with particular reference to the drawings.

1/16

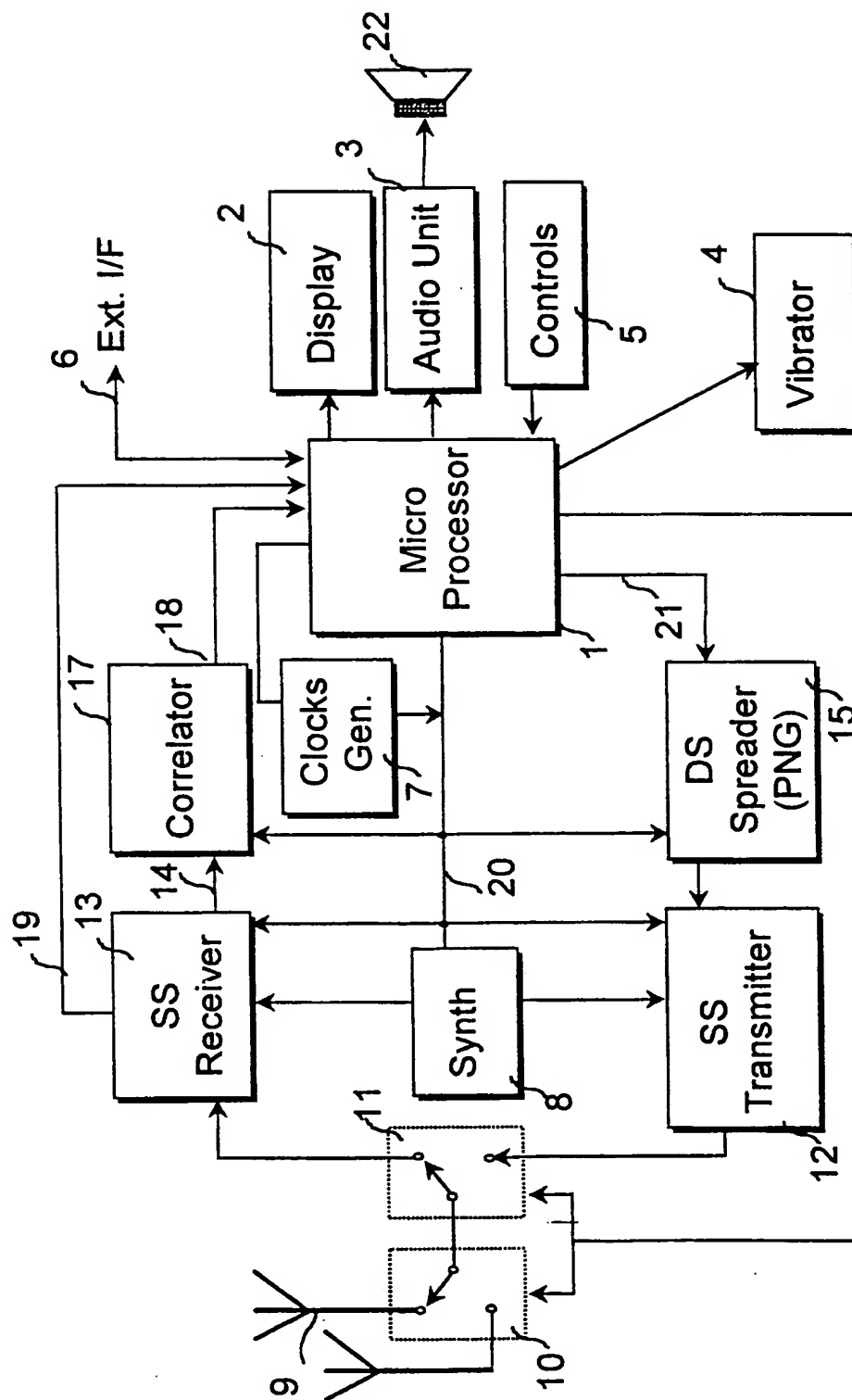


Fig. 1

2/16

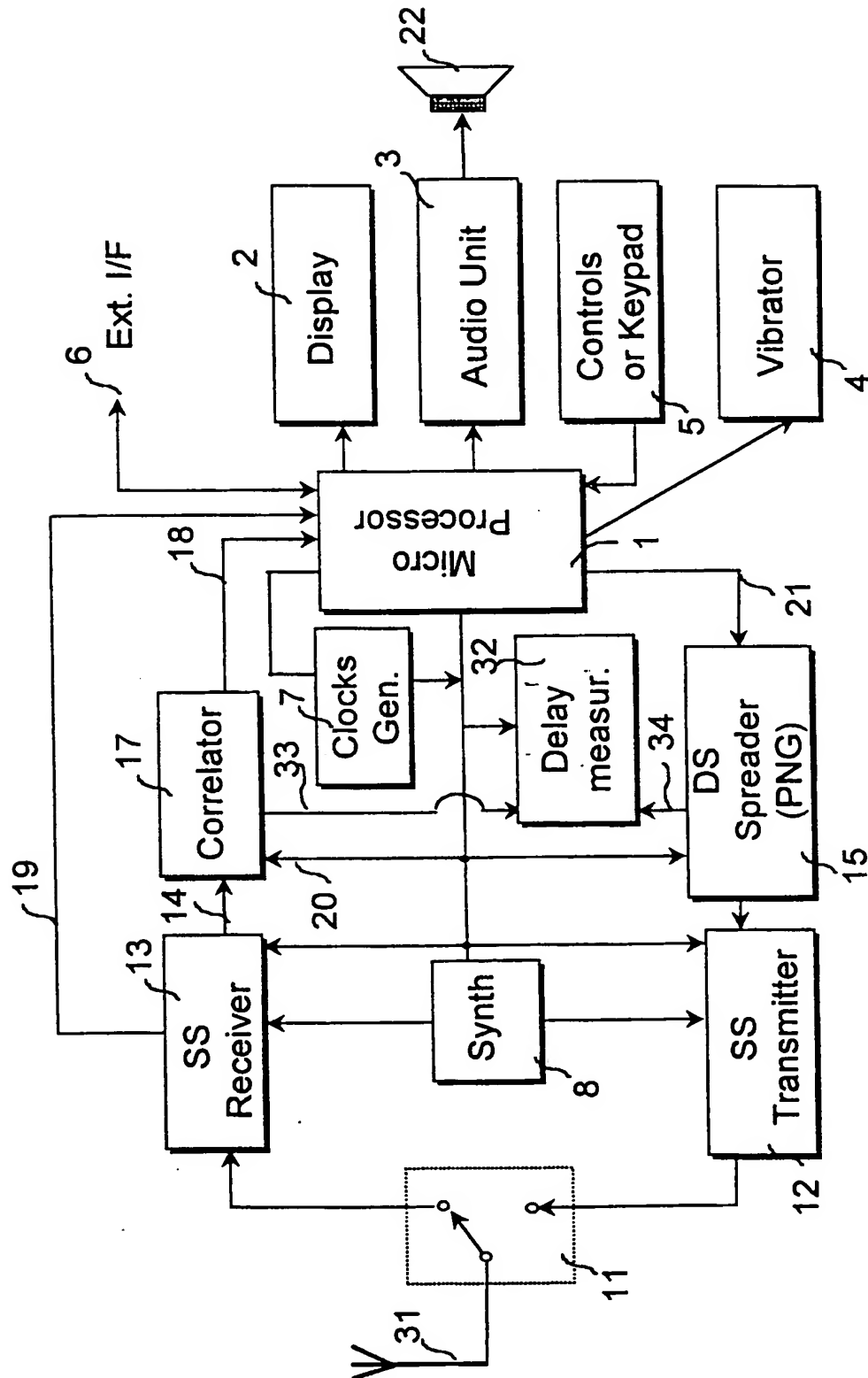


Fig. 2

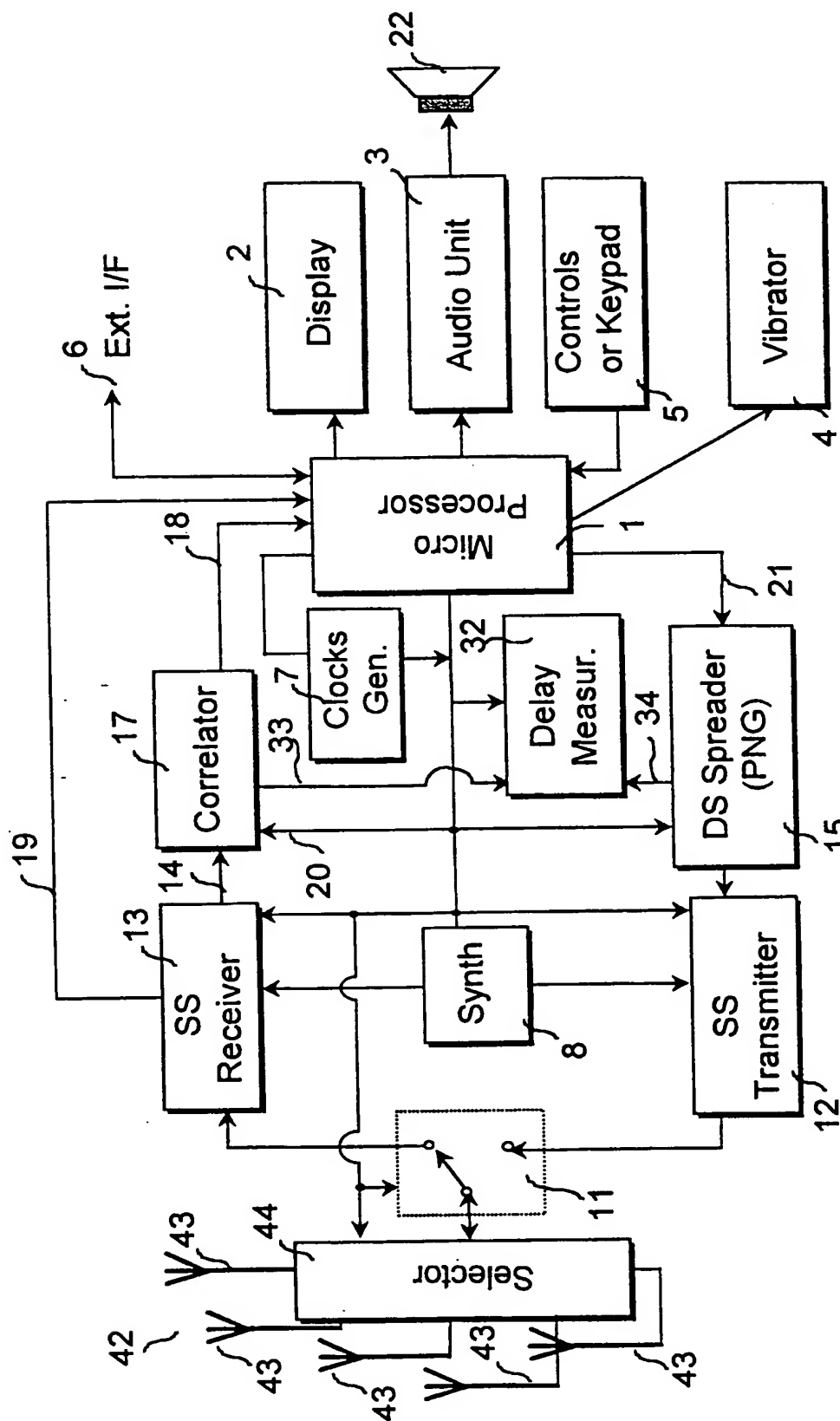


Fig. 3

4/16

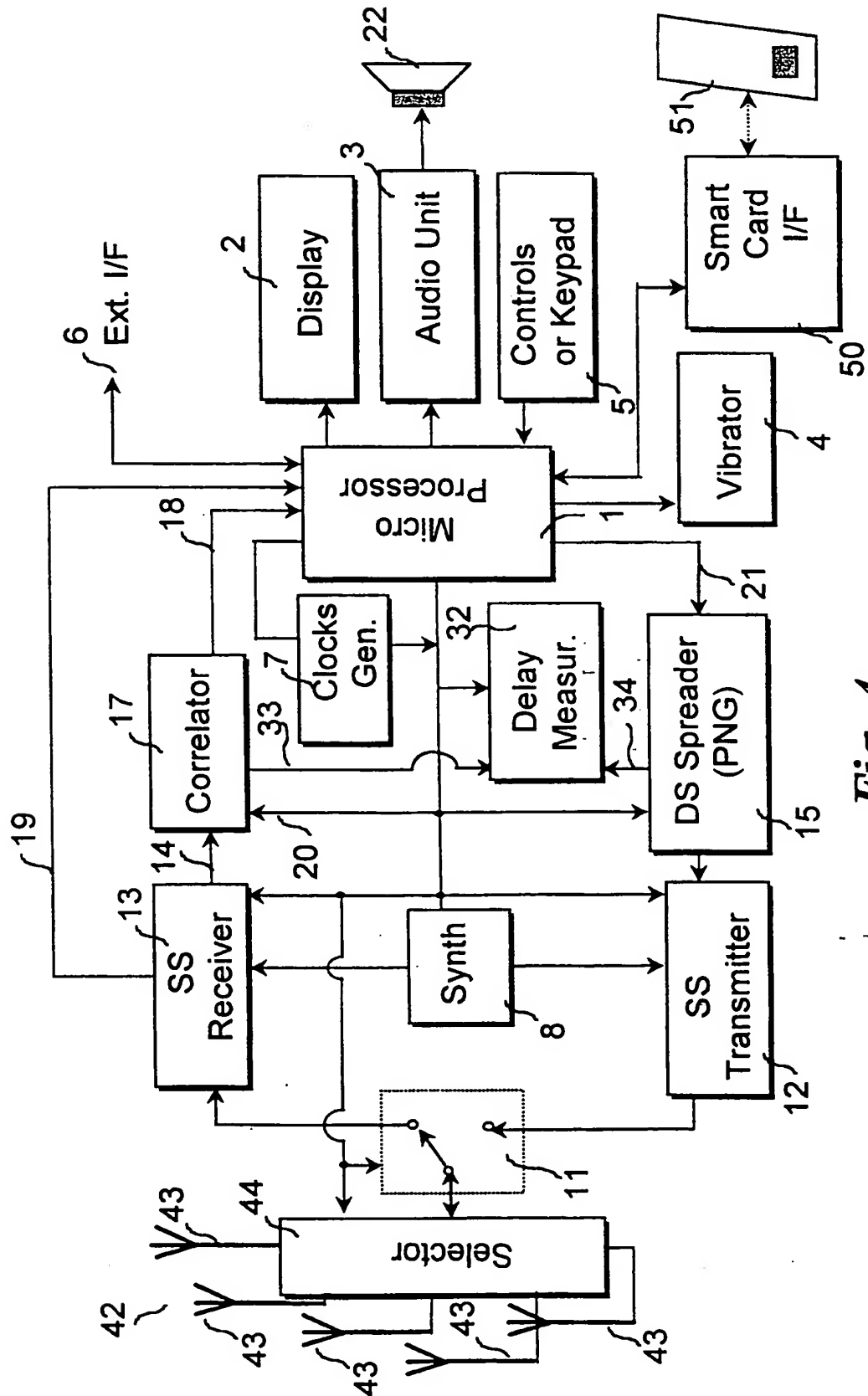


Fig. 4

5/16

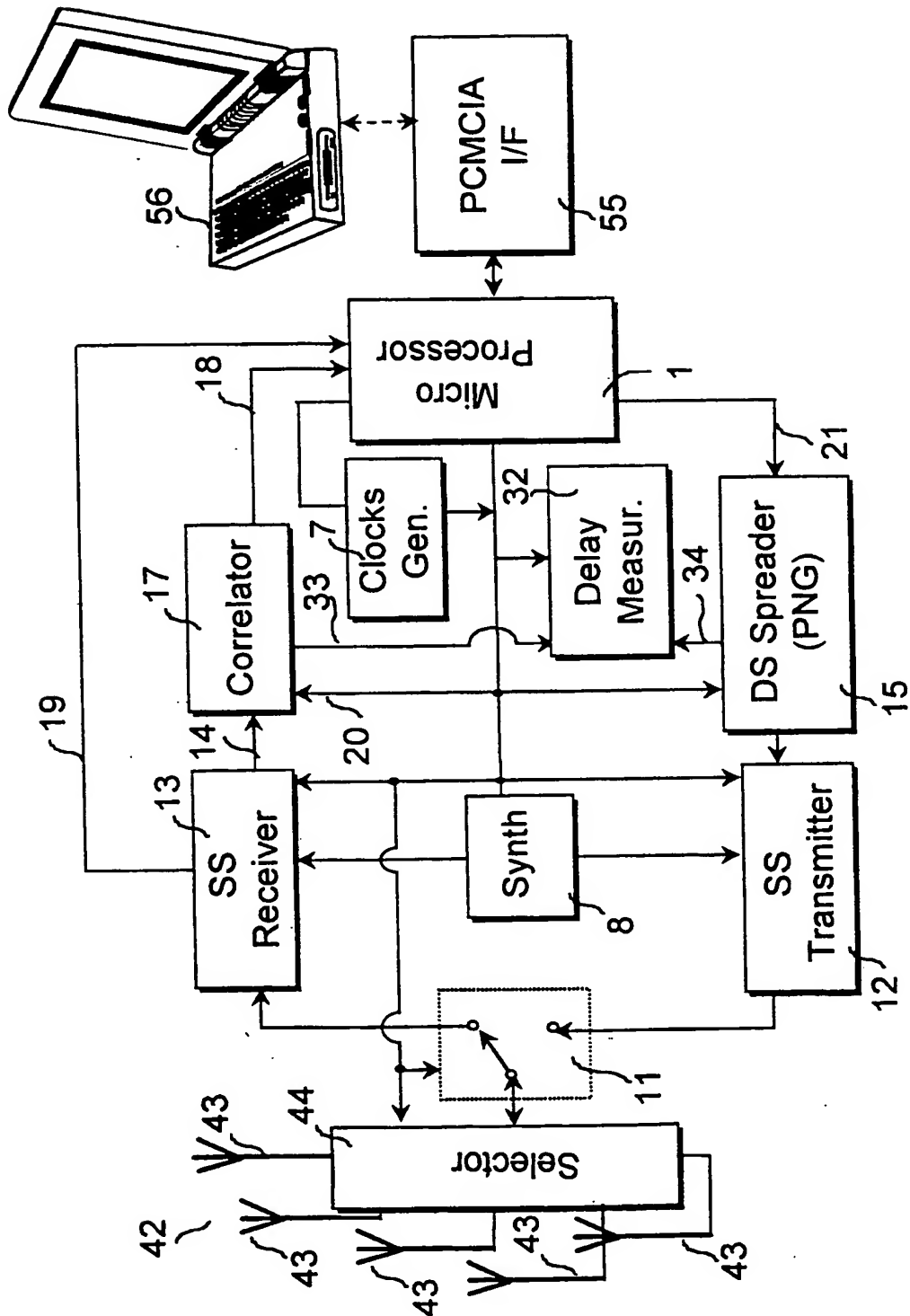


Fig. 5

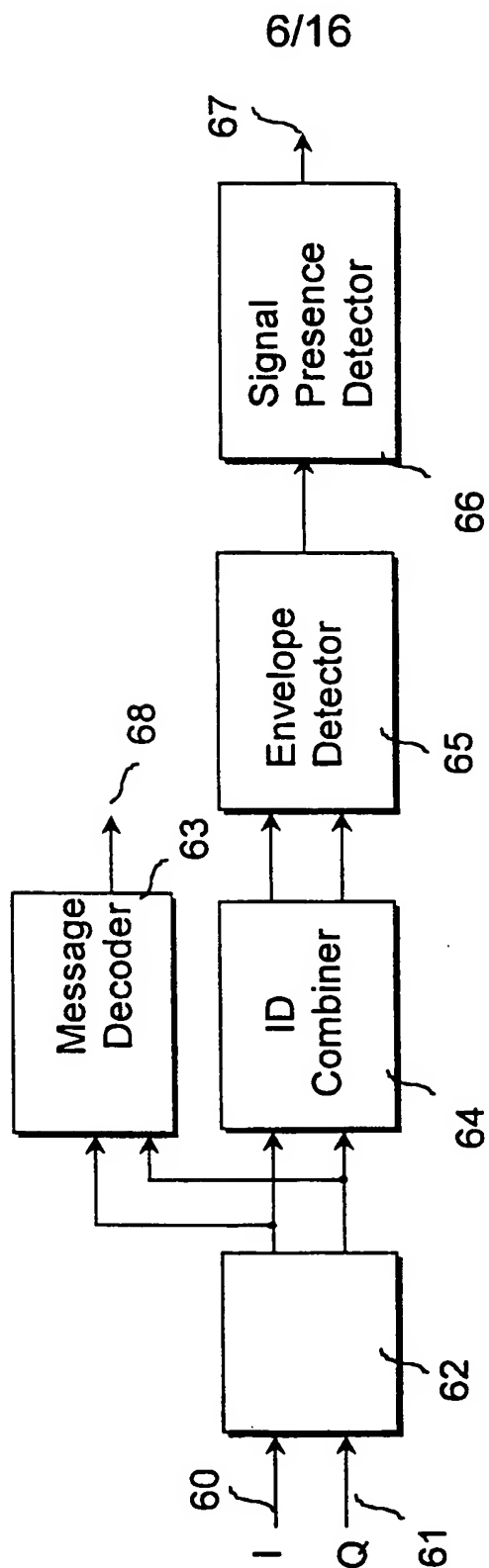
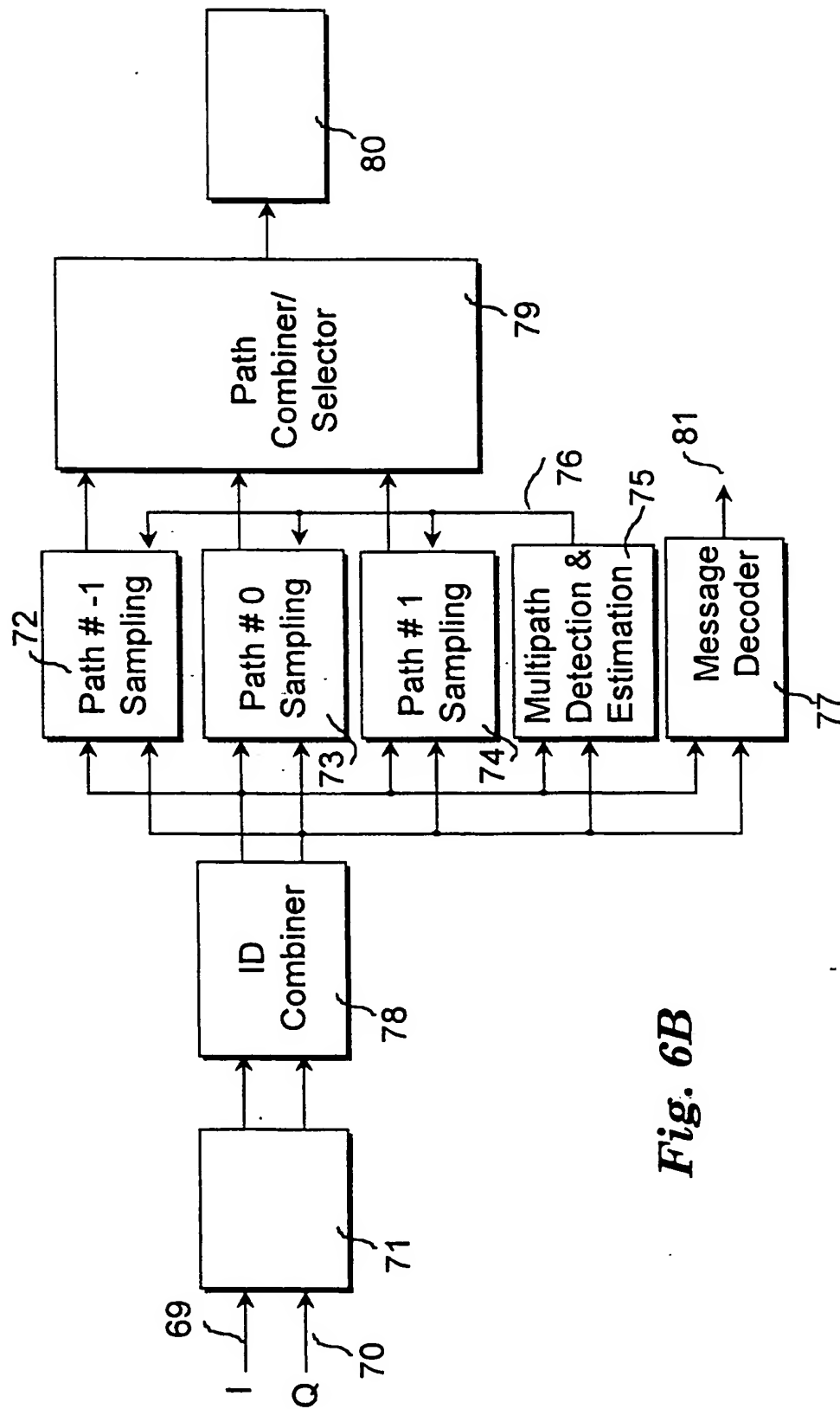
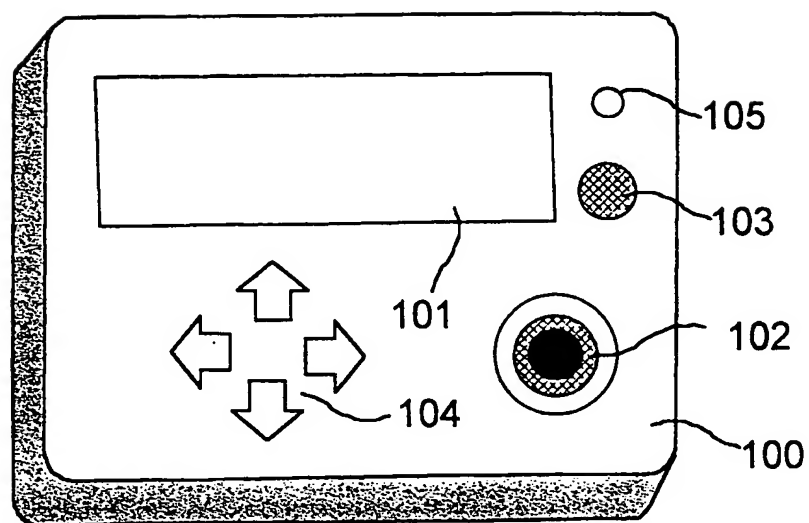


Fig. 6A

7/16

*Fig. 6B*

8/16

*Fig. 7*

9/16

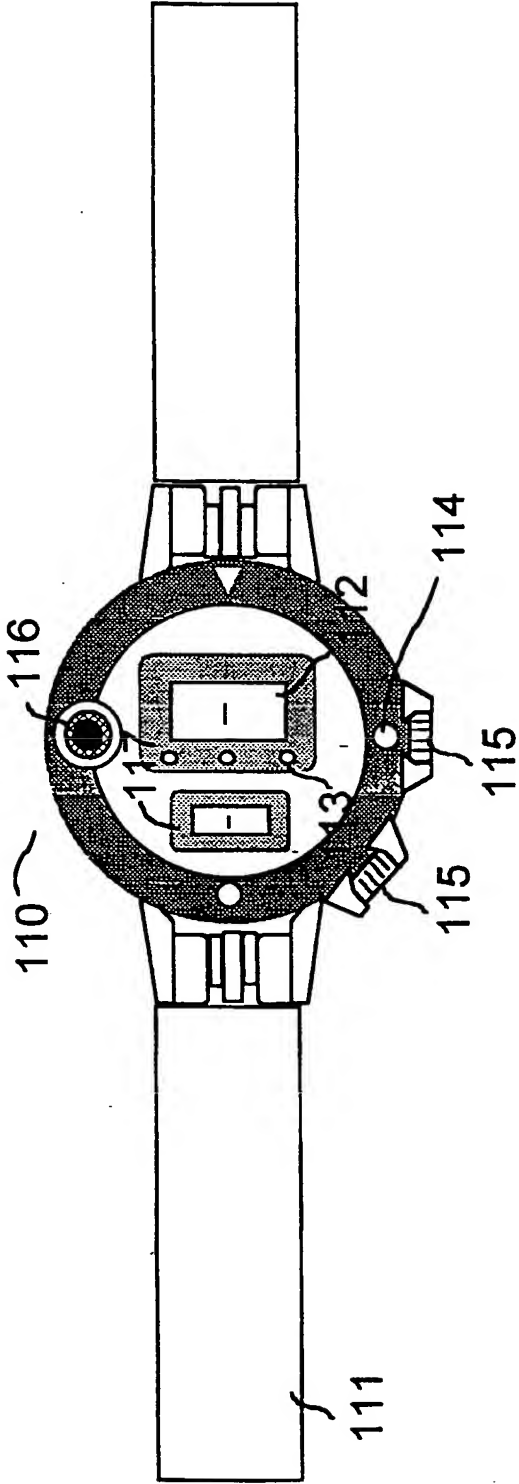
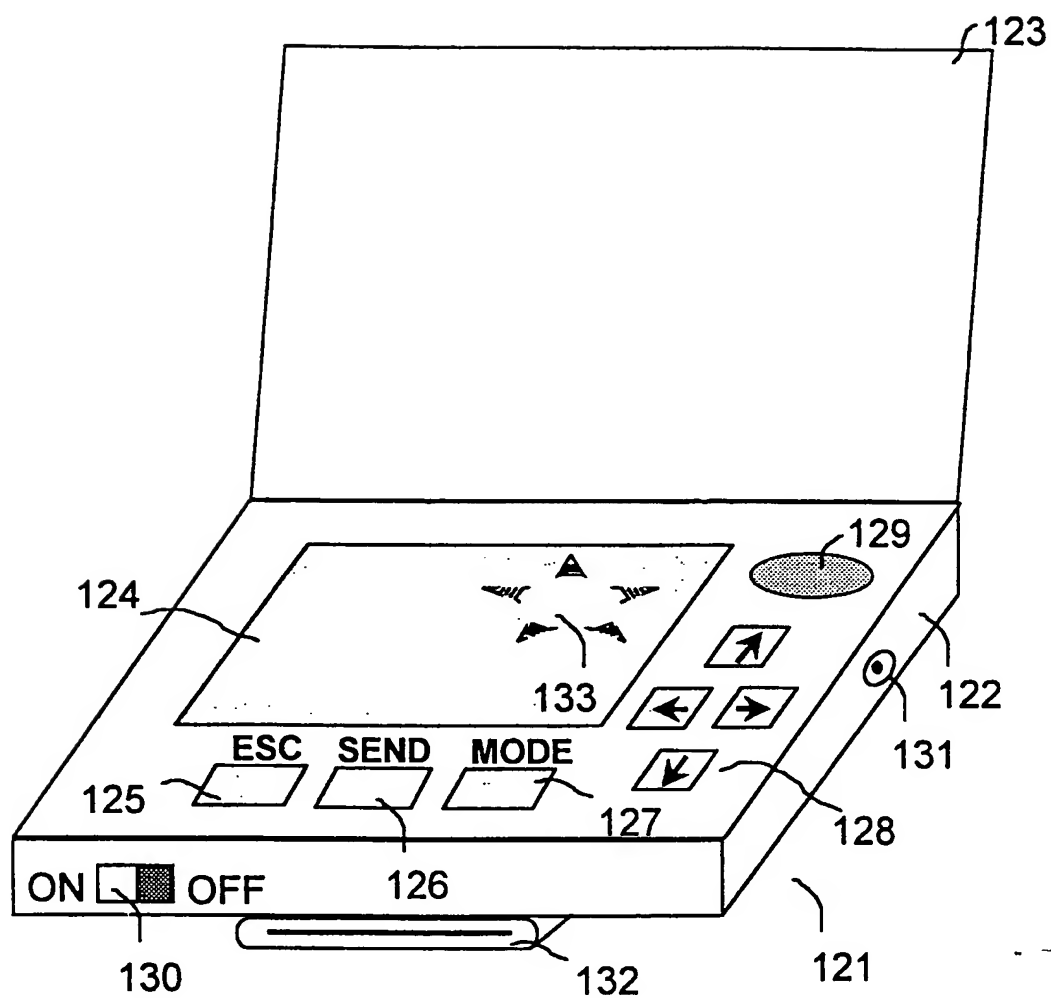


Fig. 8

10/16

*Fig. 9*

11/16

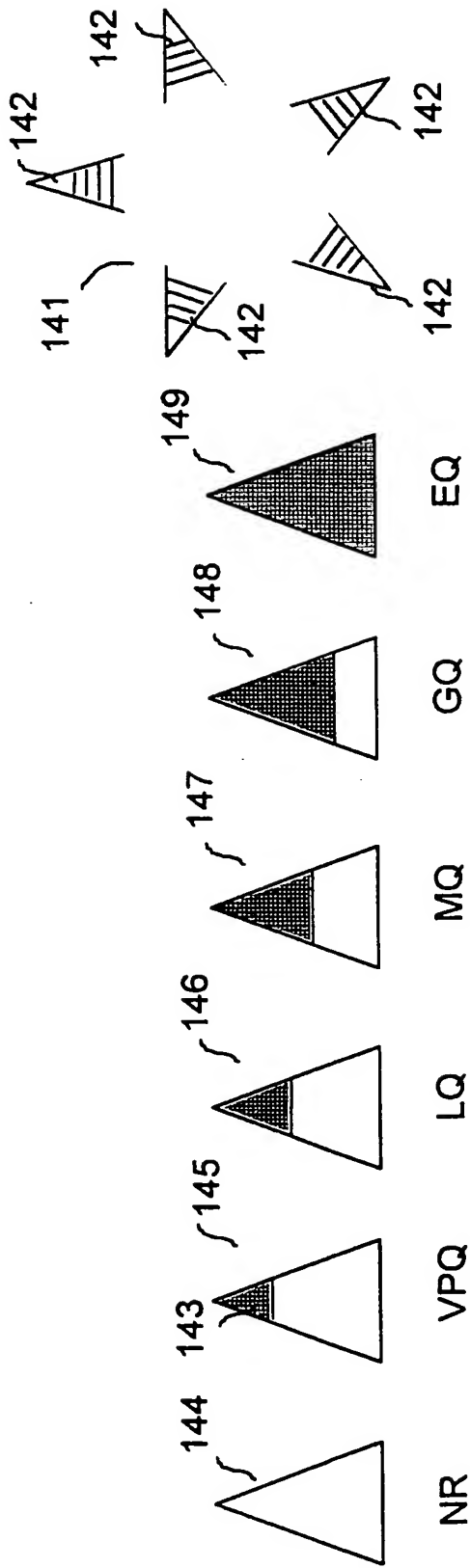


Fig. 10

12/16

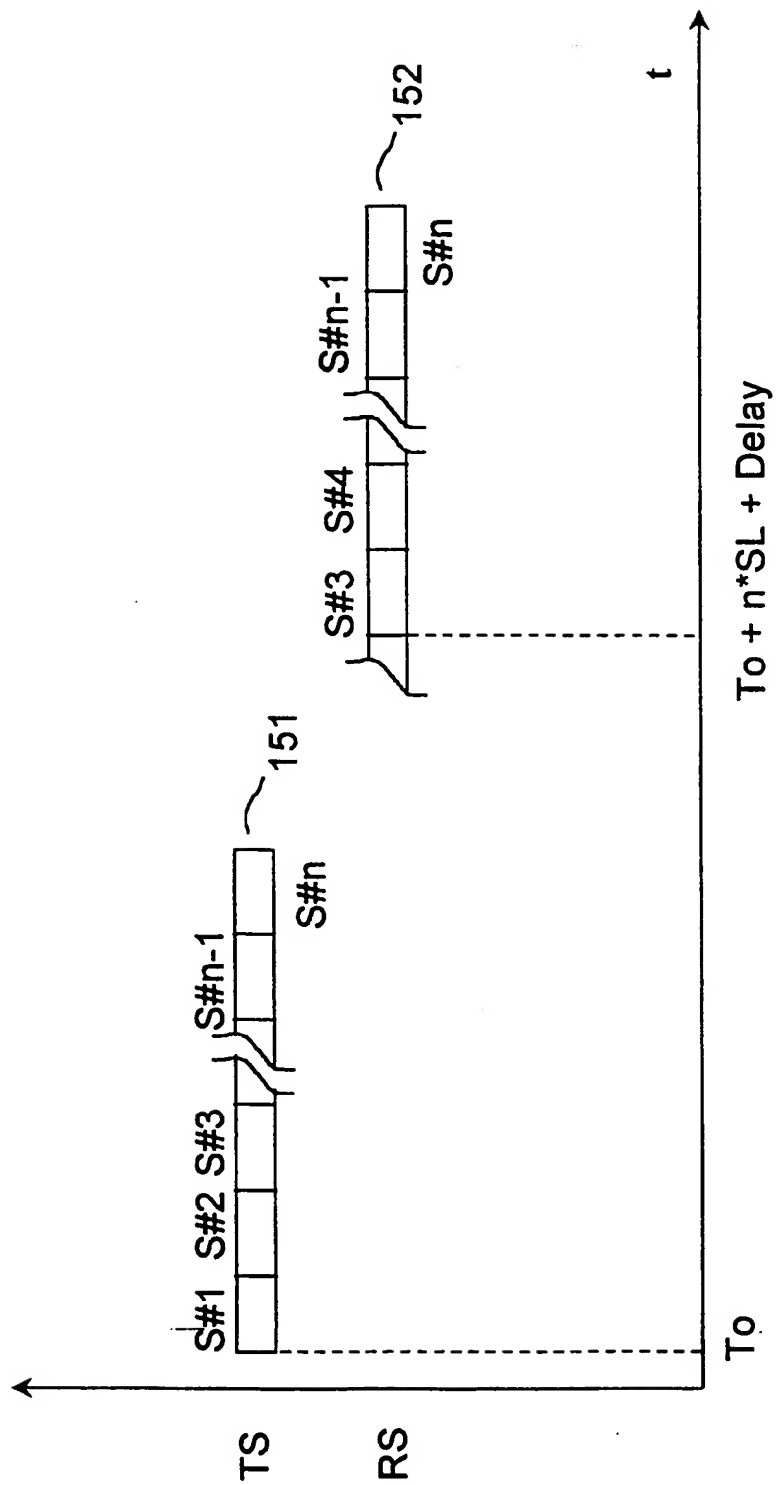


Fig. 11

13/16

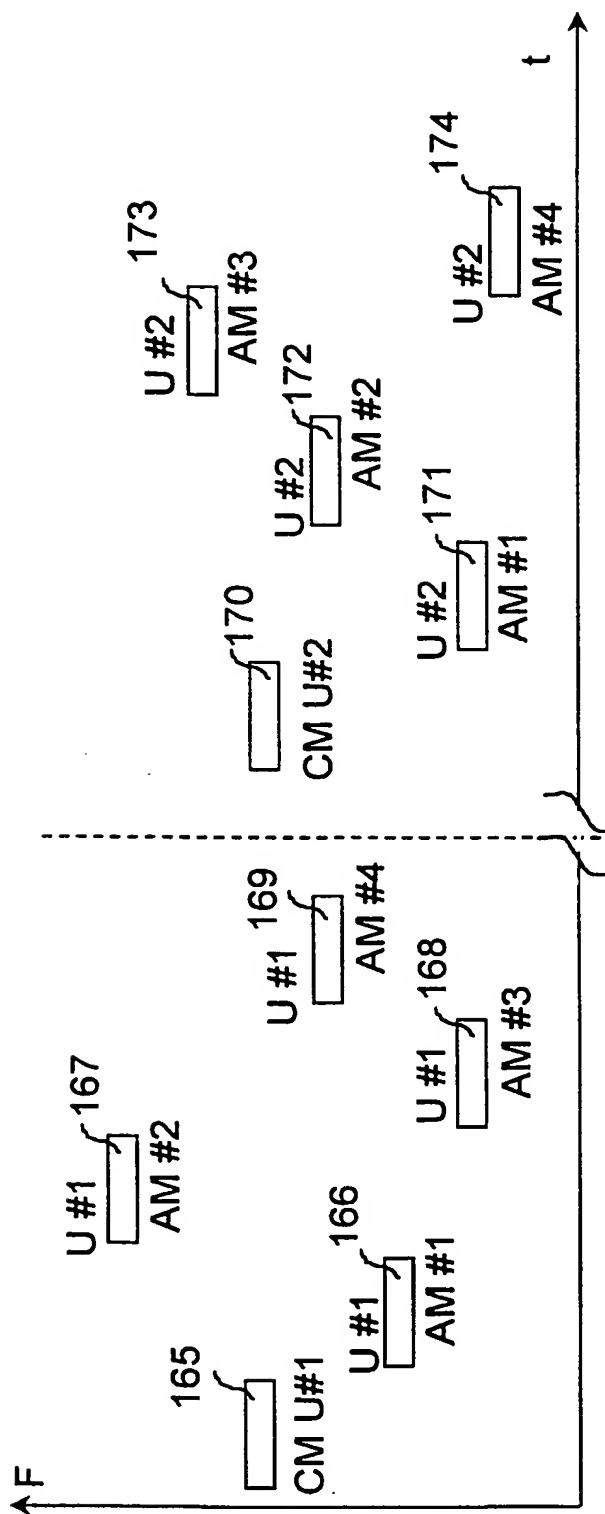


Fig. 12

14/16

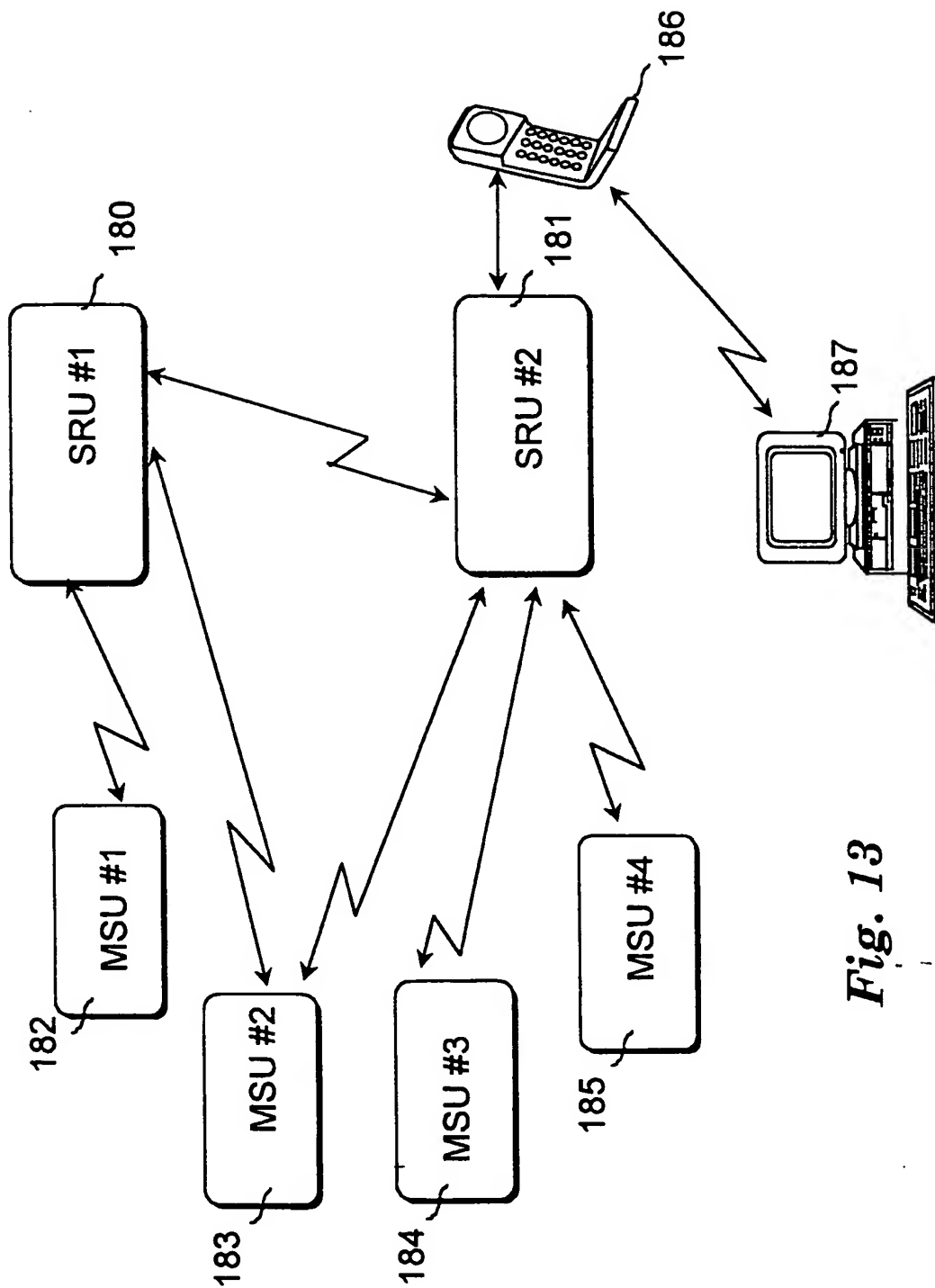
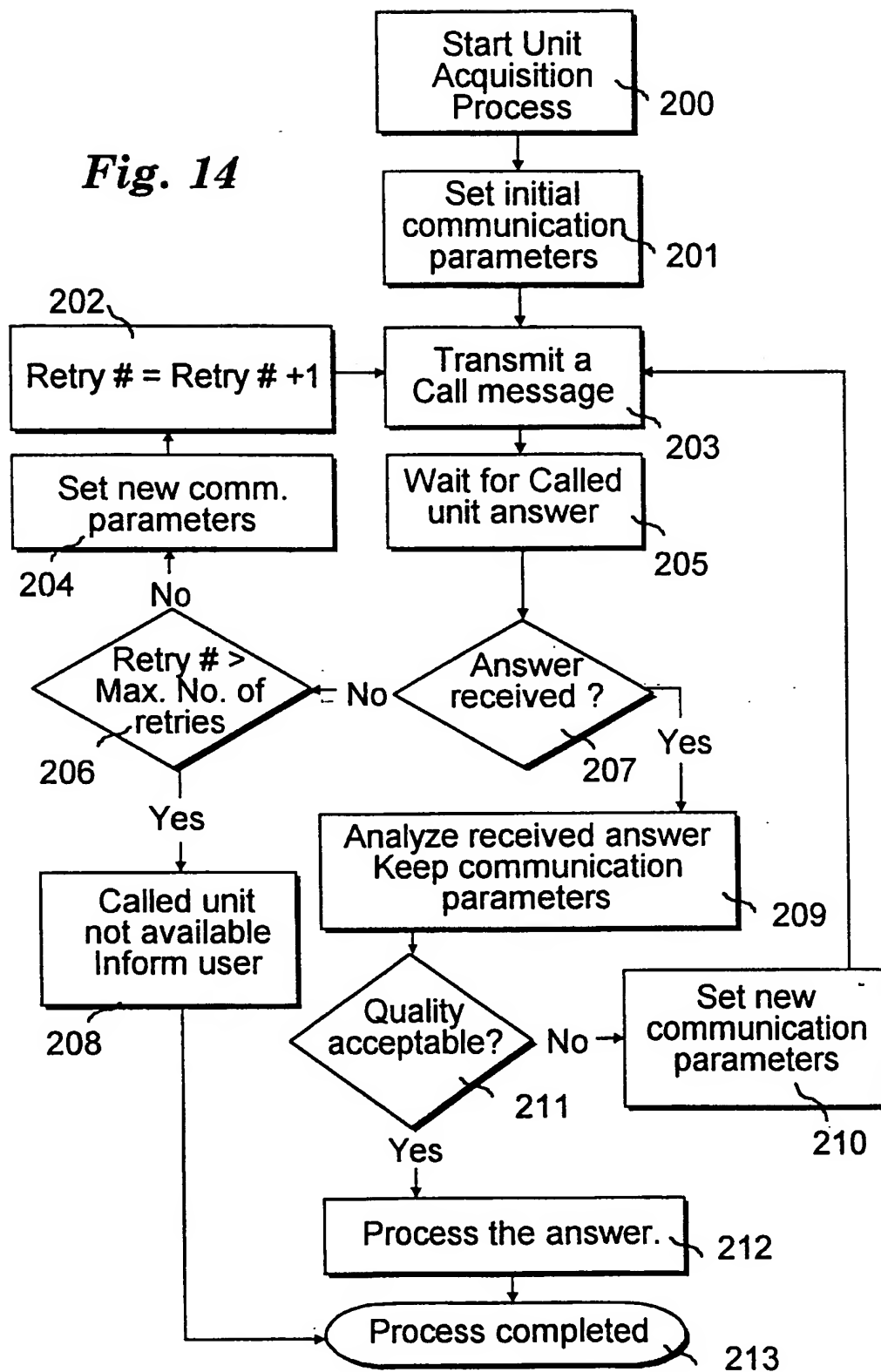


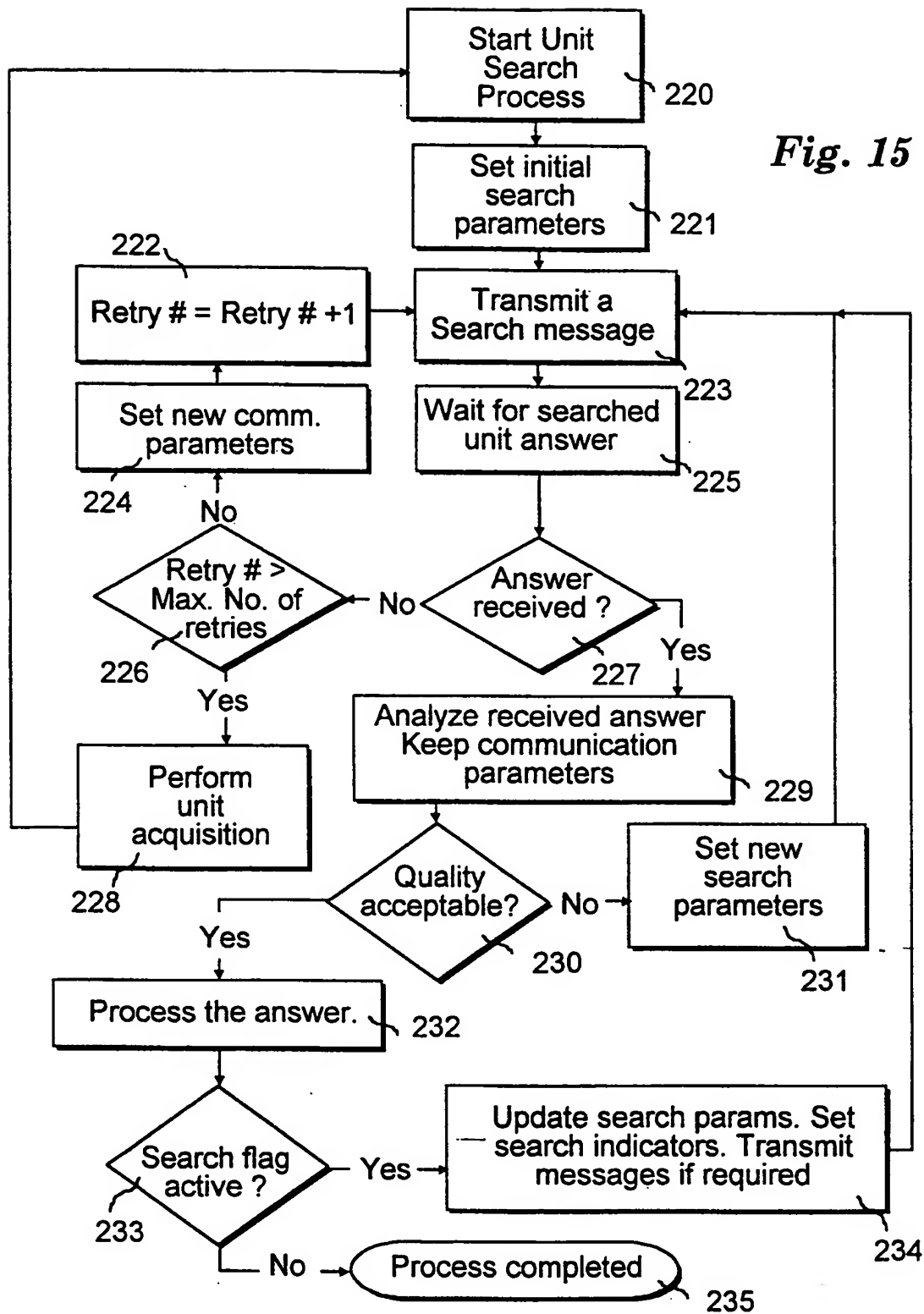
Fig. 13

15/16

Fig. 14

16/16

Fig. 15



INTERNATIONAL SEARCH REPORT

In ☐ National Application No

PCT/IL 98/00376

A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 G01S5/12 G01S13/86

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 G01S

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category * | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|------------|--|---|
| A | <p>EP 0 671 635 A (SNECMA) 13 September 1995</p> <p>see column 1, line 1 - line 6 see column 1, line 51 - column 3, line 34 --- -/--</p> | <p>1,3,5, 9-11,18, 21, 28-30, 33,35, 37,38, 40,42, 44, 49-51,58</p> |

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

21 December 1998

Date of mailing of the international search report

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Name and mailing address of the ISA

European Patent Office, P.B. 5618 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Haffner, R

INTERNATIONAL SEARCH REPORT

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